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The x-bodies in the cells of dahlia plants affected with mosaic disease and dwarf

BESSIE GOLDSTEIN

(WITH TWO TEXT FIGURES AND PLATES 18–20)

A preliminary study of the diseased dahlia plants in and about New York City indicates the existence of a group of diseases which closely resembles that group of the virus diseases loosely characterized as the degeneration diseases of potatoes. I have studied cytologically thus far two of these disease types which I characterize as 'dwarf' and 'mosaic.' 'Dwarf' dahlia plants are usually less than a foot in height, instead of the usual four feet or more. The leaves are small, though not deformed or blotched. 'Mosaic' diseased plants, so far as I have observed, are not markedly dwarfed, but are usually several feet in height, and show distinct mottling in the form of dark green patches, which may or may not be markedly bullate on the light green portions of the young leaves. Such leaves are often distorted and malformed. When flowers occur, they are often small and asymmetrical. The fact that dahlias are propagated by fleshy roots in which the causal agent may pass through the resting condition of the plant to become evident or active again in the new dahlia shoots suggests another point of similarity of these diseases with those of the potato.

I have been unable thus far to find any detailed description of a virus disease of dahlias. Eckerson (1926) mentions the mosaic disease of dahlias, and Kunkel (1926) states that the dwarf disease of dahlias is distinctly different from yellows, and not caused by virulent leafhoppers carrying the causal agent of aster yellows. A mosaic diseased condition of the dahlias at the New York Botanical Garden has been reported as possibly due to the presence of great numbers of leafhoppers.[1] Dudley and Wilson (1921), in the course of their experiments with the potato leafhoppers as the causal agent producing leafhopper-burn of

[1] The Scientific Directors. A report on scientific research. 23 p. The New York Botanical Garden: New York. 1925.

[The BULLETIN for March (54: 187–284) was issued 2 May 1927.]

potatoes, found that placing nymphs of these insects upon a dahlia plant caused it to become diseased within seven days, and finally blacken and die within twenty days. A plant under a cage free from the insects remained healthy. They suggest that the leafhoppers introduce either a toxin or a disease agent that travels down through the leaf from the regions showing the hopper-burn or yellow margined leaves (the mechanical effects of the insects themselves). The toxin or causal agent evidently causes the plants to blacken (in the case of potato) and die. This seems quite probable to me. It may very well be that the insects introduce a virus into the dahlia plants, which does not in most cases get hold of the dahlia plants in the field during the first season. The virus multiplies within the tissues upon its first introduction, and then recedes to the roots, coming up with the new shoots the next season, and perhaps several seasons thereafter. The virus is finally vigorous or plentiful enough to kill the plant. With each planting of the roots each season, the virus produces a successive series of degenerative effects, which culminate in extreme dwarfing, and the final discarding of the roots for future planting.

Cytological study of the growing points of such plants shows that the intracellular bodies associated with tobacco (Iwanowski, 1903; Palm, 1922; Goldstein, 1924, 1926; Rawlins and Johnson, 1925), with corn mosaic (Kunkel, 1921), *Hippeastrum mosaic* (Kunkel, 1922), the wheat rosette disease (McKinney, Eckerson, and Webb, 1923), and the Fiji disease of sugar cane (McWhorter, 1922, Kunkel, 1924), are also present here and resemble in many respects those associated with the mosaic disease of tobacco and apple of Sodom (*Solanum aculeatissimum*) which I have previously described (1924, 1926) and referred to as the x-bodies. The mosaic diseased leaves that show mottling are thus far the only ones in which I have found these bodies. The x-bodies found in these plants are notably amoeba-like in appearance. Eckerson (1926) refers to elongated flagellate bodies in dahlia phloem, and 'spore forms' are figured and described as present in growing points and badly mottled leaves. Since the drawings presented were made from crushed living material and their relation to the cells was not known, one cannot be certain that these bodies are the x-bodies.

The x-bodies of diseased dahlia plants are often, as noted, dis-

tinctly amoeboid in form, with short blunt pseudopodial extensions arising from the body surface (text fig. 1). The body itself may be drawn out into a single elongated pseudopod-like form, or this projection of the body may be curved back so as to form a superimposed lobe (text fig. 1 and fig. 3). The forms of the bodies as observed in various cells suggest very definitely flowing or moving actions on the part of the bodies. The pseudopods may all occur on one side of the body. Often the body shows evidence of moving forward by a simple elongation in a

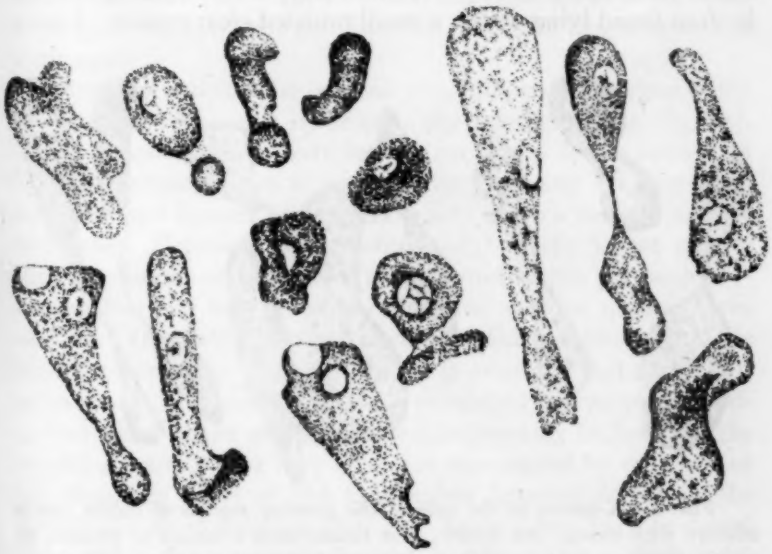

FIG. 1. X-bodies found in the cells of the growing regions of mosaic diseased dahlia plant. Drawn with the aid of the camera lucida, at a magnification of about 2100.

certain direction (text fig. 1). The bodies may be rounded or oval, or extremely elongated. The elongated ones generally occur in elongated cells, although similar elongated cells in the same row or adjacent rows of cells may contain minute or medium sized rounded or oval bodies. Small cells usually contain small bodies. Large cells, however, may contain one or several small bodies, or one or more large or medium sized bodies, or one or more small bodies and larger bodies.

The visible structure of the x-bodies is very much like that of

protoplasm (figs. 2 and 12, and text figs. 1 and 2), being finely granular, fibrillar, and alveolar in different regions. They often contain vacuoles (figs. 5 and 14, and text fig. 1). The occurrence of vacuoles on the periphery of these x-bodies (fig. 19) is rather conspicuous, since their occurrence in such a region was never observed in the case of the x-bodies of tobacco. In some cases the limiting membrane is gone, leaving a distinctly rounded indentation on the surface of the body (text fig. 1).

Structures within the material of the body resemble small nuclei (text figs. 1 and 2). A small body with radiating threads is often found lying within a small rounded clear region. I have

FIG. 2. X-bodies in the cells of the growing regions of dahlia plants affected with mosaic and dwarf. The bodies show evidence of division by constriction.

not found a ring of dense granular material around these structures such as I have found to occur so often in the case of the x-bodies I have described in tobacco plants (1926).

I have found figures that may be taken as representing every stage in the division of these bodies by constriction, from very slight equatorial narrowing to complete division and separation (text fig. 2). Kunkel (1924) has figured a constricting body in a cell of a gall on a sugar cane plant affected with the Fiji disease. In some cases the content of the body has completely divided and rounded up into separate masses (figs. 6, 7, 8, 9, 11, and 17), while the membrane stretched and constricted between them is

still intact. In other cases the membrane is drawn out into a fine thread still connecting the daughter bodies. Sometimes the bodies are small and rounded, and show a very dense content, as if encysted. Such encysted forms have been described by McWhorter (1922) for the amoeboid organisms associated with the Fiji disease of sugar cane. In many cases such bodies show slight light staining pseudopod-like extensions from the dense rounded portion. When such extruded pseudopods are rather elongated, the center of the body shows a large central vacuole within the cyst. McWhorter (1922) has reported that the cysts in the galls of sugar cane germinate to produce a single amoeboid body again.

Often the x-bodies lie in close proximity to the nucleus of the cell, pressed up against it, or partially surrounding it (fig. 15). Such positions of the x-body in close proximity to the nucleus of the cell, pressing upon it or partially enclosing it, have been described and figured by Kunkel (1921) in corn mosaic, and by McKinney, Eckerson, and Webb (1923) in the wheat rosette disease. In one cell the x-body was found within the nucleus—intranuclear, as has been described for various animal virus diseases. One cell shows an x-body in direct contact with the nuclear membrane. The membrane is extended and drawn out into a sharp point, and this point is enveloped by two pseudopodial extensions of the x-body. The x-bodies may be found in the central vacuole, where they often are surrounded by the more or less shrunken mass of the tanniferous network found in the vacuoles in fixed material (fig. 1). Again, they may be found lying within the cytoplasm proper, usually within a thick cytoplasmic bridge crossing the cell space (figs. 12, 14, 16, and 21).

The process of the distribution of these bodies by cell division of the host cell (figs. 4, 18, 20, and 21) is even more marked and conspicuous here than in tobacco, where I (1926) have also figured the various stages in the division of the host cell, with the final distribution of the x-bodies present in the cytoplasm to the two daughter cells. However, in the dahlia I have found a great deal of evidence to show that a more or less definite position is taken up by the several bodies present in the dividing cell with reference to the daughter nuclei and the cell plate forming. In one cell I have found an x-body at each pole of the spindle at the equatorial plate stage (fig. 20). In another cell containing a

dividing nucleus in late telophase, the phragmoplast fibers have nearly reached the lateral walls, the daughter nuclei lie close to the young cell plate, and beside each daughter nucleus lies an x-body (fig. 21). A somewhat similar figure is also shown by Kunkel (1924) in a cell of a gall from a sugar cane plant affected with the Fiji disease. A very striking case is that of a cell in which the daughter chromosomes lie on the spindle in an anaphase position half way between the middle of the spindle and the poles. Alongside the spindle are two x-bodies, each on a level with the daughter chromosome groups. Moreover, these bodies show evidence of recent division and separation, in that the elongated portion of each lies on the adjacent surfaces of the bodies. Sometimes more than one body may be left in one cell, or several may be left in one cell, while only one is left in the other.

I have suggested before (1924, 1926) that these bodies may be plastic enough to pass through the pores of anti-bacterial filters. On the margins of my sections I have often found the nuclei, which represent very dense protoplasm, passing through the Tangl lines or plasmodesmen which are invisible under my highest magnifications. Nakahara's (1926) observations of filterable cells of chicken sarcoma, if confirmed, would strengthen the viewpoint that these bodies are also not too large to be the causal agent of the mosaic diseases. The x-bodies are not of the nature of tannin, as shown by the ordinary tannin tests, and by the presence in the same cells of tannin grains, vesicles, and tanniferous networks. They are not distorted conditions of any of the organelles of the cell, since they may be found in cells containing the nucleus of the cells, plastids, tannin deposits, and fine protoplasmic strands crossing the central vacuole, very much as in a normal cell. They are not hypertropied plastids, since they are found even in the cells of the growing point, where plastids have not yet been formed. They are not products of fixation, since they can be found in the cells of material studied in the living condition, as well as in material fixed by various methods of fixation and stained with various stains. They are definite entities in the cells of diseased regions of diseased plants, and show by their appearance in the cells that they cannot be considered simple degeneration products of the host cell, or cell nucleus, because of their very protoplasmic appearance and

structure, and the presence within them of internal vacuoles and nuclear-like structures, the presence of peripheral vacuoles, their apparent division by constriction, and their remarkable distribution to the daughter cells on the division of the host cell.

I wish to acknowledge my indebtedness to Dr. R. A. Harper for his advice in this study and in the preparation of this paper.

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Explanation of plates

The photographs were made with a Zeiss microscope from stained and sectioned material. The magnification is about 1200 diameters.

PLATE 18

FIG. 1. A parenchyma cell near the growing point. A very dense x-body lies within a tanniferous network in the central vacuole. The nucleus lies against a lateral wall of the cell, and contains a single nucleole.

FIG. 2. A portion of a cell containing a nucleus against the lateral wall, and a large x-body in the central vacuole.

FIG. 3. Portion of a cell containing a somewhat elongated and curved x-body. The nucleus of the cell contains a nucleole.

FIG. 4. A cell containing a division figure at a late telophase stage. The daughter nuclei lie close to the forming cell plate. The phragmoplast is supported within the central vacuole by strands of cytoplasm. Below the figure, an x-body lies in one of these cytoplasmic strands. Above the figure, and close to the daughter nucleus lies a second x-body.

FIG. 5. Two cells in a leaf primordium. The dark small bodies are young plastids. An x-body is present in each cell. One cell also shows the nucleus as a small oval body containing a single dark nucleole lying against the lateral wall.

FIG. 6. A cell containing a constricting x-body. One portion of the x-body is attached to the nuclear membrane, and has pulled it to a point and away from the content of the nucleus.

PLATE 19

FIG. 7. Cells from the midrib of a leaf primordium. The nuclei are deeply stained and lie against the lateral walls. The small oval bodies are young plastids. In one cell the x-body appears quite rounded. In the other cell, the x-body has divided, and the two daughter portions are still enclosed within the unbroken limiting membrane of the original body.

FIG. 8. A cell containing a constricting x-body. The nucleus of the cell lies against the lateral wall. The content of the x-body has completely divided, leaving a clear region within the constricting central region.

FIG. 9. A cell containing a constricting x-body. The content of the body has already moved apart, leaving a clear region within the constricting but still unbroken membrane.

FIG. 10. A young tube cell in which three small x-bodies lie within a cytoplasmic strand above the cell nucleus.

FIG. 11. A similar cell in which the x-body is dividing by constriction.

FIG. 12. A portion of a cell near the growing point. The nucleus is somewhat irregular in form, and contains a single large nucleole. The x-body present is distinctly protoplasmic in appearance and lies within the cytoplasmic threads, which through shrinkage lie away from the bounding walls.

FIG. 13. A group of four cells in a leaf primordium. Each contains an x-body.

FIG. 14. A cell containing a single vacuolate x-body, lying within a thick cytoplasmic bridge crossing the cell vacuole.

PLATE 20

FIG. 15. A cell in which the x-body is partially enveloping the nucleus. The nucleus contains three nucleoles.

FIG. 16. An elongated tube cell containing a single x-body at one end of a protoplasmic strand, and an oval nucleus at the other. The nucleus contains a dark nucleole.

FIG. 17. Three elongated cells below the growing point, each showing the presence of an x-body. In the third cell the x-body is dividing by constriction. The lower portion of the body is very amoeboid in appearance. The upper portion appears smaller than the other half because of the presence of a large pseudopod-like extension upward, which could not be shown in the plane of the picture.

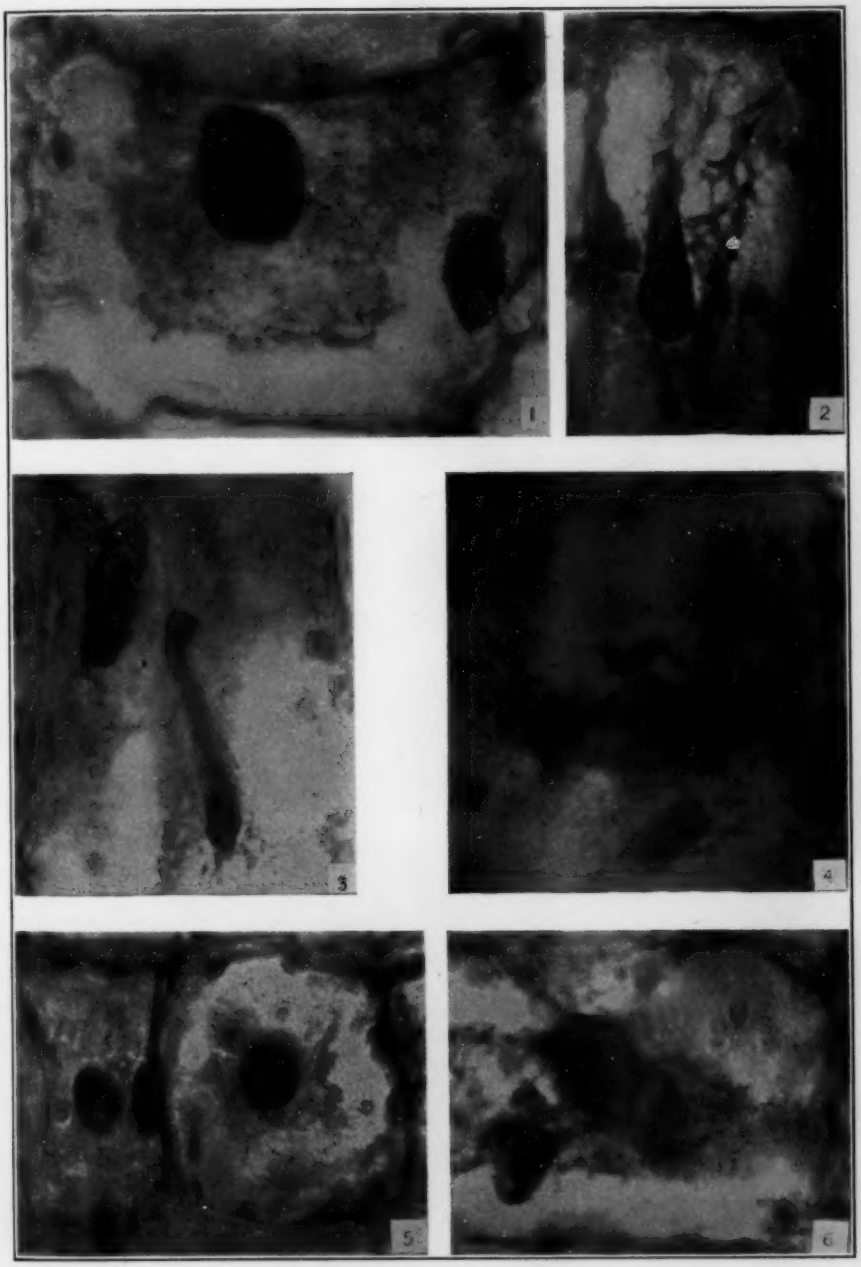
FIG. 18. Two young daughter cells. The daughter nuclei are still pressed up against the young cell plate. An x-body lies in each daughter cell.

FIG. 19. An amoeboid x-body showing the presence of peripheral vacuoles bounded by limiting membranes.

FIG. 20. A cell containing a spindle figure at the equatorial plate stage. An x-body lies near each pole of the spindle.

FIG. 21. Two groups of daughter cells. Each daughter cell contains a nucleus, and an x-body within the protoplasmic sheath against the young cell plates.

FIG. 22. A cell containing an irregularly shaped nucleus, within which lies a single nucleole, and an elongated x-body.



THE X-BODIES ASSOCIATED WITH DAHLIA MOSAIC

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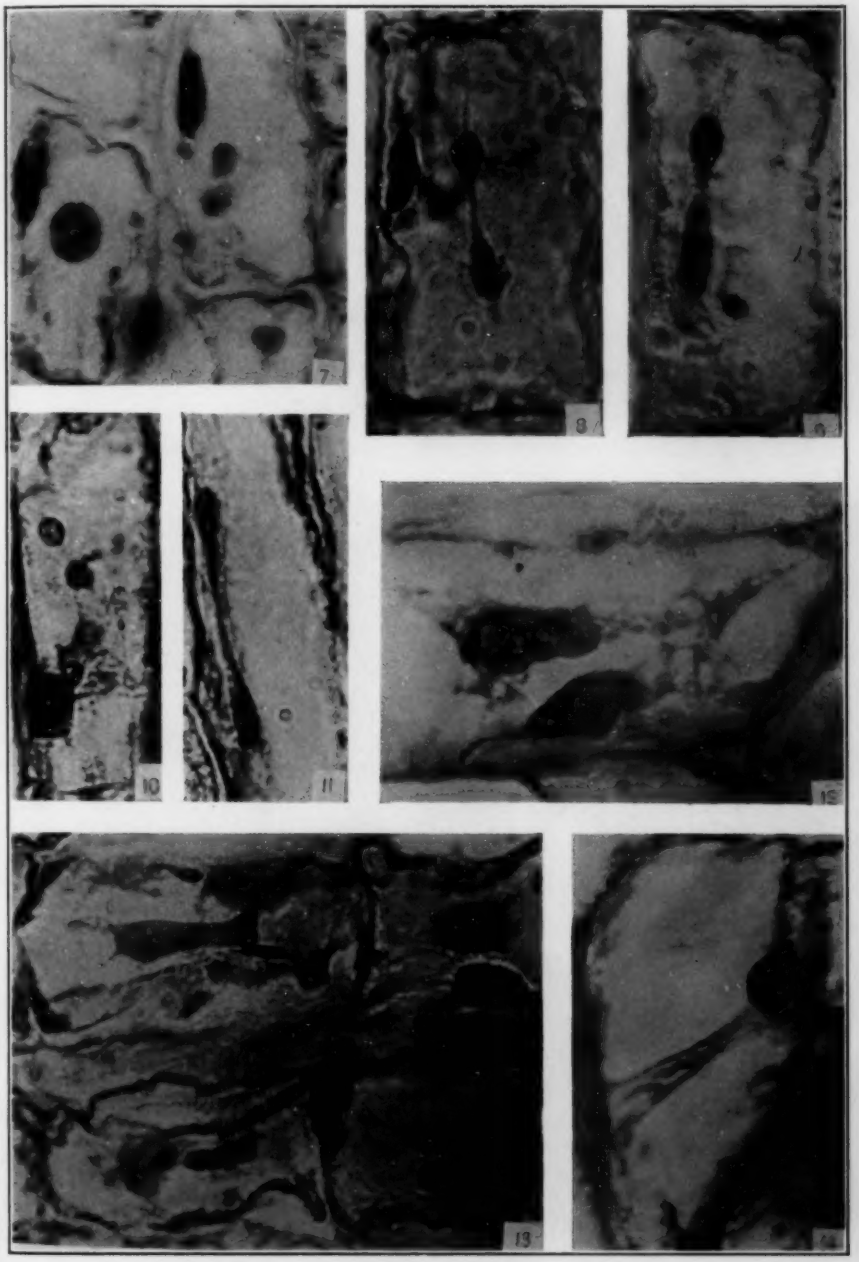

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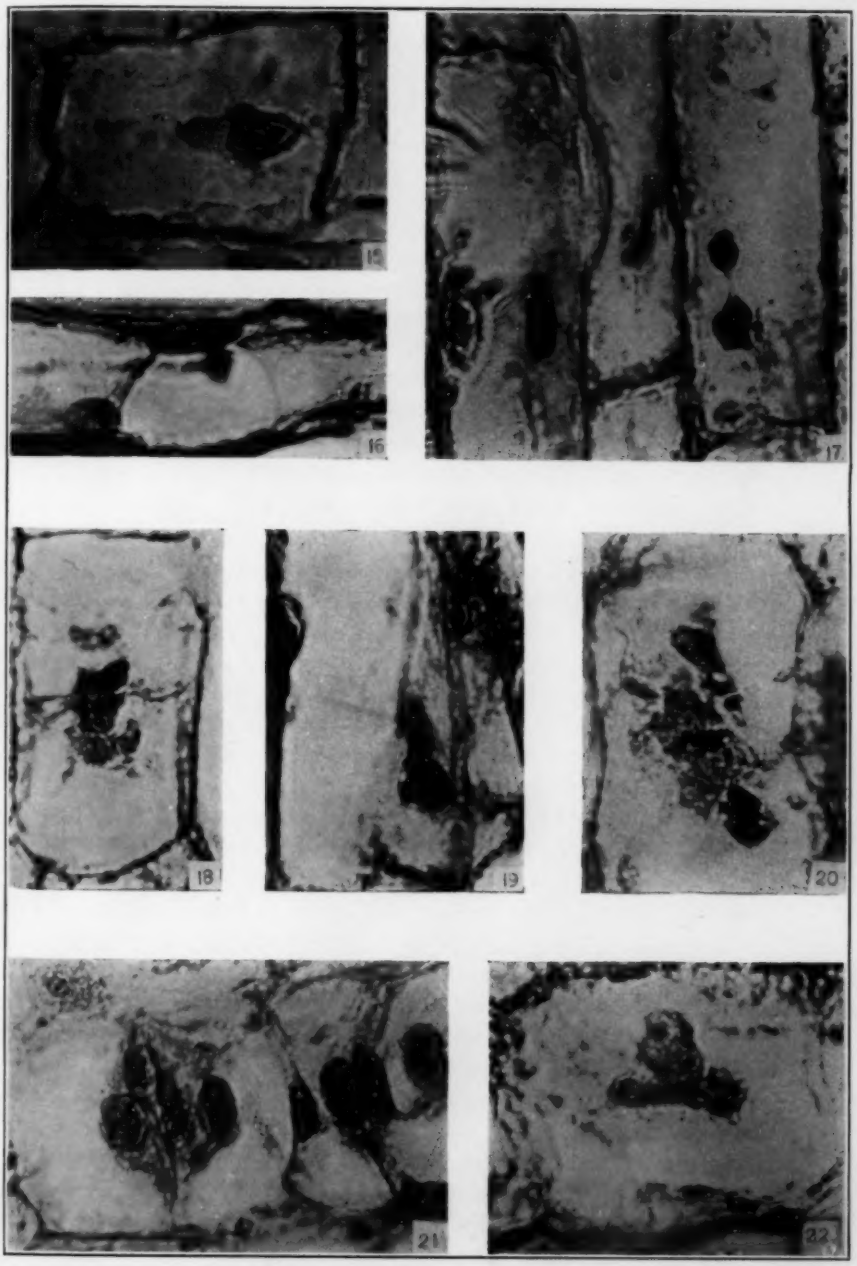

THE X-BODIES ASSOCIATED WITH DAHLIA MOSAIC

Experimental studies on head smut of corn and sorghum[1]

GEORGE M. REED, MARJORIE SWABEY, AND LAURA ALMA KOLK

(WITH PLATES 21–25)

The head smut of corn and sorghum caused by *Sorosporium reilianum* (Kühn) McAlpine is unusually interesting on account of its occurrence on both these hosts, which belong to two distinct genera of grasses—Zea and Holcus. Corn or maize is a new-world plant, having been brought into cultivation by the American Indians, and, since the discovery of the Western Hemisphere, the plant has been carried to various parts of the world; wherever adapted to the climatic conditions, as in Southeastern Europe, some parts of India, Australia and South Africa, it has become an important crop. Sorghums, on the other hand, have been cultivated for many centuries in various parts of the old-world, particularly China, India and parts of Africa. The wild forms, such as Sudan Grass and Tunis Grass, are distributed in Central and Southern Africa, Egypt, Madagascar and neighboring islands.

It is noteworthy that corn is attacked by another kind of smut, *Ustilago zeae* (Beckm.) Ung., which, so far as known, is incapable of attacking sorghum. This smut, usually known as common corn smut, is widely distributed and is recognized as one of the most serious diseases of this cereal. The sorghums also are attacked by several species of smut in various parts of the world, the most widely distributed being the covered kernel (*Sphacelotheca sorghi* (Link) Clinton), and loose kernel (*Sphacelotheca cruenta* (Kühn) Potter) smuts.

The head smut fungus was first described as *Ustilago reiliana* by Kühn (13) in 1875, his description being based on a specimen on sorghum from Egypt which Dr. Reil sent to him in 1868. Cooke (5), in 1876, collected head smut on corn in India, describing it under the name of *Ustilago pulveracea*, and Passerini (21) in the same year described a form on corn in Italy as *Ustilago reiliana* f. *zeae*. The fungus is now known to be widely distributed on both crops and has been recorded from practically all regions where sorghum and corn are extensively grown (24).

[1] Brooklyn Botanic Garden Contributions, No. 51.

Head smut was first recorded on sorghum in the United States in 1890 by Failyer and Willard (8), who collected a single specimen on Red Liberian Sorgo in Kansas. Professor S. M. Tracy (24) collected specimens on sorghum in November, 1888, at Starkville, Mississippi, but no record was made until later (25). Since its discovery the fungus has been recorded on sorghum from several states. As a rule it is not particularly common, occurring only sporadically, but in the Panhandle Region of Texas, it is recognized as a parasite of considerable economic importance.

Norton (19) made the first record of its occurrence on corn in the United States in 1895, and during that season it apparently was not uncommon in certain fields in Kansas. The disease, however, has not been frequent on corn in the United States, being practically unknown east of the Great Plains, including the great Corn Belt. It has, however, been found recently by Mackie (14) in a field of King Philip maize near Stockton, California and Dana and Zundel (6) in 1919 found it in two fields in the vicinity of Pullman, Washington, in one field 40 per cent of the plants being smutted. Parker (20) has more recently noted its wide distribution in that State. The fungus is common, and causes a serious disease in parts of Australia (16), South Africa (7, 17, 18) and India (2).

Head smut appears to be a characteristic systematic disease. The parasite enters primarily through the young seedling and continues its development as the host increases in size. There is no special indication of stunting of an infected sorghum plant; in fact there is practically no indication of infection until about the time that the plants are ready to head out. Just previous to heading, the infected plants can be distinguished from the normal by the more rapid enlargement of the panicle enclosed by the sheath of the upper leaf. Frequently the terminal head is entirely converted into a smut ball, which is more or less cylindrical in shape. It is rather hard and firm and covered with a thick white membrane which easily splits and exposes the spores surrounding the remnants of the vascular tissue of the various parts of the panicle. In some cases, branches of the panicle escape infection, the smutted portions being confined to single branches, or even spikelets. Usually small pustules of spores are found on these, but there are also cases in which the spikelets are stimulated to develop into a leafy shoot without further in-

dication of the formation of spores. Sometimes the terminal head of the plant is entirely sound, but smutted lateral heads arise from the upper nodes of the main stem. In still other cases the main stem may produce only sound heads, while secondary stems arise from the ground level which have their panicles converted into the characteristic smut balls (pl. 24 and 25).

On corn the smut balls appear on both the tassel and the ear. Occasionally the terminal part of the stem is transformed into one large pustule and, due to the shortening of the internodes, appears surrounded by a rosette of leaves. In other cases, the tassel shows more or less its usual form; some of the spikelets produce normal flowers with stamens while others are transformed into smut balls. Occasionally the infection is confined to individual spikelets of the tassel and frequently a characteristic development of shoot-like structures is stimulated. On the ear, the individual kernels are transformed into masses of smut spores. In the early stage they rapidly enlarge, remaining more or less distinct. Soon, however, the covering membrane disappears and the individual smut pustules more or less coalesce into a dusty mass of spores. Sometimes an excessive number of ear-like structures develop at the various nodes on the stem of the plant, each developing into a smut ball. The tassel may entirely escape infection, while the disease appears on the ear, no cases, however, being observed in which the tassel showed infection while the ears remained normal (pl. 21, 22 and 23).

A number of workers have endeavored to produce artificial infection of sorghum and corn by the head smut fungus. The usual procedure has been to inoculate the seed with the spores. Brefeld (1) reported that Kühn succeeded in producing infection of sorghum with both head smut and loose kernel smut on the same plant. Passerini (22) was able to infect corn, but not sorghum, using spores collected on the former. Kellerman (10, 11) and Kellerman and Jennings (12) carried out a large number of inoculation experiments without, however, having obtained any marked degree of success in securing infection. McAlpine (15) succeeded in infecting only one corn plant by seed inoculation, while Clinton (4) and Hori (9) obtained entirely negative results in their experiments.

Potter (23) has made an extensive study of the life history of head smut. He also obtained essentially negative results when

he tried to infect sorghum plants by inoculating the seed with spores and he then tried other methods of inoculation, such as mixing the spores with the soil and covering the seed or seedlings with this mixture. By these procedures he was able to obtain a considerable degree of success and as a result of his studies he came to the conclusion that the occurrence of infected plants is due to the presence of spores in the soil, where they may retain their viability for considerable periods of time. He also concluded that seed-borne spores are of minor importance in producing infection.

Christensen (3) has recently recorded the results of his studies on the relation of soil temperature and soil moisture to the occurrence of head smut of sorghum. His method of inoculation consisted of planting the seed in a soil mixed with the spores of the fungus. He was able to secure infected plants over a wide range of temperature—16 to 36° C.; a comparatively dry soil proved much more favorable for infection than a moist soil, his highest infection being 46.5 per cent.

Potter (23) concluded that the soil at the Amarillo Field Station, Texas, where many of his experiments were carried out, was thoroughly infested with the spores of head smut. A large number of varieties of sorghum have been grown at this Station by the Office of Cereal Investigations (24), and the occurrence of head smut on them has been recorded, the observations being made during the years 1916, 1917 and 1919. It is interesting to note that Feterita, the Milos and Broom Corn proved to be entirely free from infection. An occasional infected plant was found among the Kafirs and Kaoliangs, while the Sorgos as a group proved to be susceptible. The results, however, indicated that only eight varieties of sorghum grown during these years gave indications of moderate susceptibility. These were Black Amber, Minnesota Amber, Early Rose, Red Amber and Coleman Sorgo, Brown and White Durra and Giant Schrock Sorghum. Since the infections depended upon spores present in the soil, it was not possible to be certain of a thorough inoculation of every plant. Equal opportunities for the penetration may have been lacking, due to the unequal distribution of the spores in the soil. However, the observations showed that certain groups of sorghum consistently remained free from head smut.

The studies here reported are mainly concerned with the

question regarding the possible relation between the head smuts on corn and on sorghum. They are recognized as belonging to the same species, as no morphological differences are observable which might serve to distinguish them. The records of their occurrence, however, indicate that the fungus may be present on one host in a given locality, while in a different area the other host is the one affected. This may be due in part, at least, to the fact that the crops are not generally grown in the same localities. However, a certain amount of overlapping occurs in the areas of their cultivation, and hence if the disease is common on one host, it might be expected to be more or less frequent on the other. In Western Kansas and Texas head smut on certain varieties of sorghum is fairly common. No recent records of its occurrence on corn have been made. In Washington the disease has been noted as rather severe on corn. It is also common on corn in Kashmir, India, and somewhat less frequent in the Punjab and Northern Bombay. In other parts of India the disease occurs on sorghum, being more frequent in Bombay. It is also fairly common on corn in parts of Australia, but has not been reported upon sorghum. The question arises, then, as to whether the two smuts are identical in their capacity for infection or whether they show distinct physiologic specialization.

In carrying out these investigations, it has been necessary to try various methods of inoculation. Some experiments have also been made regarding the influence of various environal factors on infection.

METHODS AND RESULTS FOR 1924

A series of experiments with the head smut of sorghum was carried out in 1924. The variety Red Amber Sorgo, which was known to be moderately susceptible to this disease, was inoculated with spores collected on this variety during the previous season. The usual procedure was to place the dry seeds or seedlings on soil in a paraffin cup; these were then covered with a mixture of spores and soil, prepared by adding a definite quantity of spores to the soil. The spore-soil mixture was applied at once or after standing a definite number of days. In most of the experiments the soil contained a moisture of about 40 per cent of its water holding capacity, and the seedlings were germinated in the laboratory, where the temperature usually varied from

18 to 22° C. After emerging from the soil they were transplanted to the field, where they were allowed to grow to maturity.

Three distinct series of experiments were carried out, the results being given in table 1. In the first series a freshly prepared mixture of spores in soil was placed over seedlings which varied from one to seven days old. At the end of one day the

TABLE I

Inoculation experiments with head smut of sorghum—1924. Spores from Sorgo on Red Amber Sorgo

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEEDLINGS	TOTAL NO. OF PLANTS	NUMBER INFECTED	PERCENTAGE INFECTED	LENGTH OF PLUMULE AT TIME OF INOCULATION
	days	*days*				*mm.*
I	0	1	16	5	31.2	
	0	2	10	2	20.0	2
	0	3	20	9	45.0	3- 5
	0	3	14	4	28.5	5–10
	0	4	15	4	26.7	10–20
	0	5	7	0	0	20–30
	0	7	10	0	0	40–60
II	1	1	20	12	60.0	
	2	2	18	3	16.7	2
	3	3	19	0	0	5–10
	4	4	22	5	22.7	10–20
	5	5	17	1	5.9	20–30
	7	7	14	0	0	40–60
III	1	0	10	2	20.0	
	2	0	18	5	27.8	
	3	0	17	2	11.8	
	4	0	18	0	0	
	5	0	15	0	0	
	6	0	15	0	0	
	8	0	17	0	0	
	9	0	15	0	0	
	10	0	15	0	0	

only signs of germination were the increased size of the seed. At the end of two days, however, the average length of the plumule was 2 millimeters. As the seedlings grew older the length of the plumule increased until at the end of the seventh day it varied from 4 to 6 centimeters in length. In this series infections occurred in the experiments where the seedlings used

were one to four days old, the percentage of smutted plants varying from 20 to 45 per cent. No infection occurred in seedlings that were five and seven days old respectively. The results indicate that infection readily occurs by means of a fresh spore-soil mixture on seedlings whose plumule is not over 2 centimeters in length.

The second series of experiments consisted of inoculating seedlings successively one to seven days old with a spore-soil mixture of a corresponding age. Infections occurred in all except two of the experiments. A three day old spore-soil mixture gave negative results on seedlings three days old, but this was probably an accidental result in the experimentation. The seven day old spore-soil mixture also gave negative results on seedlings of the same age. In the other successful experiments the percentage of infection varied from 5.9 to 60 per cent. The latter occurred in the experiment in which seedlings one day old were inoculated with a spore-soil mixture which had been prepared for one day.

In the third series, dry seeds were inoculated with spore-soil mixtures of various ages, from one to ten days. Infection occurred in the first three experiments in which the spore-soil mixture was one to three days old, 11.8 to 27.8 per cent infection resulting. Negative results were obtained in the other experiments.

METHODS AND RESULTS FOR 1925

Two sets of experiments were carried out in 1925, in one of which the spores of head smut collected on Red Amber Sorgo in the experiments of the previous year were used for inoculation, and, in the other, spores collected on corn were used. The head smut on corn was obtained from Dr. F. D. Heald and Dr. E. F. Gaines of the Washington Agricultural Experiment Station, who kindly collected and forwarded it for our experimental purposes. The data are recorded in table 2.

Methods and results with head smut from corn. The experiments with the head smut from corn were started July 1 to 3. The germinations were carried out in the laboratory, where the temperature varied from 18° to 22° C. and the inoculated seedlings were planted in a sandy soil which contained about 40 per cent of its water holding capacity.

TABLE 2

Inoculation experiments with head smut of corn and sorghum—1925

SOURCE OF SPORES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEED-LINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Per-centage infected	Total no. of plants	Number infected	Per-centage infected
	days	*days*						
Spores	0	0	37	7	18.9	38	0	0
from	0	3	37	11	29.7	33	0	0
corn	1	1	61	48	78.6	93	0	0
	3	3	30	21	70.0	25	0	0
Spores	0	0	49	0	0	43	10	23.2
from	1	0	—	—	—	42	4	9.5
Red	1	1	213	0	0	212	10	4.7
Amber Sorgo	3	3	49	0	0	43	3	6.9

In one series of experiments a freshly prepared mixture of spores and soil was applied to dry seed of both corn and sorghum, and also to seedlings 3 days old; 18.9 and 29.7 per cent of the corn plants respectively were infected. In a second series of experiments a spore-soil mixture one day old was applied to seedlings of the same age and 78.6 per cent of the corn plants were infected. Finally, a spore-soil mixture three days old was applied to seedlings of the same age, 70 per cent infection being obtained. The Red Amber Sorgo inoculated in the same series of experiments gave no infection, a total of 189 plants being grown in the three series.

Methods and results with head smut from sorghum. Most of the experiments with the head smut of sorghum were started on May 23 to 25. A number of different experiments were carried out, involving variations in the nature of the soil, its moisture content, the temperature and age of seedlings. In many of these entirely negative results were obtained, and most of them seemed to be without special significance. In table 2 are recorded the data for the experiments, which correspond rather closely to those carried out with the head smut of corn.

The highest percentage of infection of Red Amber Sorgo was obtained when a fresh spore-soil mixture was applied to the dry seed, 23.2 per cent of the plants being smutted. In all the other

experiments a comparatively low percentage of smutted plants resulted. In these experiments corn also was inoculated with the spores from sorghum, but no infections occurred, although a total of 311 plants were inoculated and grown to maturity.

METHODS AND RESULTS FOR 1926

A much more extensive series of experiments, in which spores of head smut collected during the previous season on both corn and sorghum were used for inoculation, was carried out in 1926. The methods consisted in various modifications of those used during the previous season. Generally, the seeds or seedlings were placed on moist soil in a paraffin cup and covered to a depth of about ¼ inch with a mixture of spores and soil, the amount depending upon the size of the seedlings. The cup was then filled with additional moist soil to the required depth and germination continued in the constant-temperature tank at 20° C. Soon after emerging, the seedlings were transferred to the field, where they grew to maturity.

The spore-soil mixture consisted of one part of spores to four parts of soil. The freshly prepared mixture was applied to the dry seed or seedlings in one series of experiments, and after standing at room temperature for a definite number of days, in the others. In most of the experiments thirty seeds or seedlings were inoculated, and in the case of sorghum, these were all placed in one paraffin cup, but on account of the size of the corn seedlings, only ten or fifteen were planted in a cup. Previous to inoculation the seeds were germinated between moist filter paper in Petri dishes and, so far as possible, seedlings of the same size were selected for the inoculation. No accurate measurements of the size of the plumule were kept, but they corresponded, in a general way, to those recorded in table 1.

Results with spores of head smut from corn. Five series of experiments were carried out in which various combinations of spore-soil mixtures and seed or seedlings were used, the data being summarized in table 3. In the first series a freshly prepared spore-soil mixture was applied to dry seeds or seedlings, one to three days old; in every case high percentages of infection, varying from 76 to 91.6 per cent, were obtained. In the second series of experiments the spore-soil mixture was one day old, and this was applied either to dry seeds or seedlings one to three days

old; in this case also high percentages of infection, ranging from 75.8 to 90 per cent were secured. A two day old spore-soil mixture was used in the third series, and again high percentages of infection resulted, varying from 38.4 to 78.2 per cent. In the

TABLE 3

Inoculation experiments with head smut of corn—1926

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEEDLINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Percentage infected	Total no. of plants	Number infected	Percentage infected
	days	*days*						
I	0	0	24	22	91.6	28	0	0.0
		1	25	19	76.0	18	0	0.0
		2	29	24	82.7	20	1	5.0
		3	30	24	80.0	16	0	0.0
II	1	0	29	22	75.8	20	0	0.0
		1	29	26	89.6	25	0	0.0
		2	30	27	90.0	23	0	0.0
		3	28	24	85.7	25	5	20.0
III	2	0	26	10	38.4	25	0	0.0
		1	23	18	78.2	18	0	0.0
		2	22	16	72.7	27	0	0.0
		3	21	15	71.4	13	0	0.0
IV	3	0	30	23	76.6	29	0	0.0
		1	24	20	83.3	22	0	0.0
		2	28	24	85.7	29	3	10.3
		3	25	22	88.8	24	1	4.1
V	4	0	30	0	0.0	28	2	7.1
		1	29	0	0.0	27	4	14.8
		2	26	21	80.7	30	4	13.3
		3	29	15	51.7	28	2	7.1
		4	29	0	0.0	28	0	0.0

fourth series the spore-soil mixture was three days old, and the percentages of infection also were very high, varying from 76.6 to 88.8 per cent. In the fifth series a four day old spore-soil culture was used for inoculation. No infection occurred on the dry seeds or seedlings one day old. Negative results were also obtained on the seedlings four days old, while the three day old seedlings gave 51.7 per cent, and those two days old gave 80.7 per cent infection.

These results indicate very clearly that the corn is highly susceptible to head smut from the same host, since high percentages of infection over a comparatively wide range of conditions were obtained. There appeared to be no significant differences in the results when a fresh spore-soil mixture was used for inoculation or one that had been prepared for two to three days. Further, it seemed to make no essential difference whether dry seeds or seedlings two to three days old were inoculated. When, however, the spore cultures were four days old, differences were apparent, depending upon the age of the seedlings.

In the same series of experiments, in which Red Amber Sorgo was inoculated with spores from corn, negative results for the most part were obtained. A few smutted plants were observed, the greatest number being found in the fifth series, in which a four day old spore-soil culture was used for inoculation. In all of the experiments only 22 plants out of a total of 503 were infected. In many of these plants the main terminal head was normal, but secondary lateral smutted panicles developed. The Red Amber Sorgo, while not entirely free from attack, yet showed distinctly a high degree of resistance to the smut from corn.

Results with head smut of sorghum. The methods employed were essentially the same as with the head smut of corn, and a similar series of experiments was carried out (table 4). In the first series a fresh spore-soil mixture was placed upon dry seeds and seedlings one to three days old. The percentage of infection varied from 33.3 to 66.6 per cent. The second series of experiments, in which the spore-soil mixture was one day old, gave a somewhat higher percentage of infected plants, the variation ranging from 73.3 to 84.6 per cent. In the third series, a two day old spore-soil mixture was used, but the percentage of infection was well below that obtained in the previous series, the lowest being 25 per cent, when the dry seed was inoculated, and the highest 51.7 per cent, when three day old seedlings were inoculated. In the fourth series a three day old spore-soil mixture was used, and the highest percentage of infection in this series was 30 per cent, when the dry seed was inoculated. In the final series, a four day old spore-soil culture was used, and the highest percentage of infection obtained was 20 per cent. This occurred in the two experiments where two day old and four day old seedlings were inoculated.

TABLE 4

Inoculation experiments with head smut of sorghum—1926

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEED-LINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Per-centage infected	Total no. of plants	Number infected	Per-centage infected
	days	*days*						
I	0	0	29	0	0.0	30	20	66.6
		1	26	1	3.8	10	5	50.0
		2	30	0	0.0	20	11	55.0
		3	25	0	0.0	24	8	33.3
II	1	0	29	0	0.0	28	20	71.4
		1	26	0	0.0	15	11	73.3
		2	29	1	3.4	24	19	79.1
		3	28	0	0.0	26	22	84.6
III	2	0	26	0	0.0	32	8	25.0
		1	29	0	0.0	29	8	27.5
		2	29	2	6.8	28	9	32.1
		3	28	3	10.7	29	15	51.7
IV	3	0	26	0	0.0	30	9	30.0
		1	30	0	0.0	25	6	24.0
		2	28	1	3.5	36	4	11.1
		3	29	0	0.0	33	5	15.1
V	4	0	30	1	3.3	39	5	12.8
		1	29	2	6.8	27	1	3.7
		2	30	0	0.0	25	5	20.0
		3	30	3	10.0	32	6	18.7
		4	30	1	3.3	25	5	20.0

In the similar series of experiments in which corn was inoculated with the spores from sorgo, an occasional plant was found to be infected; out of a total of 596 in the entire series 15 plants were smutted. The evidence is quite clear that sorghum smut does not readily pass over on to corn, although to some extent it appears to be able to infect the latter host.

Influence of temperature and moisture on infection. A few experiments were carried out in which corn was inoculated with spores from the same host and germination continued in sand with varying amounts of moisture. There were four experiments in which the percentage of the water-holding capacity of the soil was approximately 20, 40, 60 and 80 per cent. In each case a one day old spore-soil mixture was applied to seedlings

of the same age. Comparatively high infections were obtained in each experiment, the lowest being 42.3 per cent in the 40 per cent moisture and the highest 71.4 per cent in the 60 per cent moisture; 50 per cent of the plants in the low moisture were infected and 51.8 per cent of the plants in the high moisture.

A similar series of experiments was carried out with Red Amber Sorgo inoculated with spores from this host, and the following percentages of infection were obtained: 19.3 per cent in the 20 per cent moisture; 3.5 per cent in the 40 per cent and also the 60 per cent, and no infected plants in the 80 per cent moisture.

Three experiments were carried out in which variations in temperature were employed. Seedlings one day old were inoculated with a spore-soil mixture of the same age, and germination continued in soil at 20°, 25° and 30° C. The corn plants inoculated with spores from corn gave 89.6, 77.2 and 84.6 per cent infection respectively; thus all these temperatures appeared to be equally favorable for the infection of the corn. With the Red Amber Sorgo inoculated with spores from sorgo, the percentages of infection at these three temperatures were 73.3, 29 and 18.9 per cent, respectively. The data suggest that a temperature of 20° is more favorable than either 25° or 30° for the infection of the sorgo.

Varietal susceptibility. A very few varieties of corn were inoculated with spores from corn. In each case one day old seedlings were inoculated with a spore-soil mixture of the same age and germination continued in soil. The results obtained were as follows: Australian Pop 48 per cent; Golden Bantam Sweet 35 per cent; King Philip Flint 66.6 per cent; Leaming Dent 66.6 per cent; Pawnee Flour 60 per cent and Washington Dent 82.1 per cent. In a similar series in which sorghum varieties were inoculated with spores from Red Amber Sorgo, using the same methods, the following results were secured: Black Amber Sorgo 38.4 per cent; Coleman Sorgo 75 per cent; Early Rose 22.7 per cent; Red Amber Sorgo 61.1 per cent; Brown Durra 3.5 per cent; Schrock Sorghum gave negative results.

DISCUSSION

The results for 1925 indicated that the corn smut would not go over on to the sorghum, since no infection occurred in a total

of 189 inoculated plants, although 87 corn plants out of a total of 165 were infected. These results showed quite clearly the high degree of susceptibility of the corn to the smut. It was further found that the sorghum smut would not pass over on to corn, a total of 311 plants being inoculated. Unfortunately, the percentage of infection of sorghum with spores from the same host was very low, only 27 plants out of a total of 340 being infected.

In 1926, however, a few corn plants inoculated with spores from sorghum and a few sorghum plants inoculated with spores from corn were smutted. Since the experiments with each smut were started at different times, and special care taken to avoid contamination, the evidence indicates that the smut may to some extent pass from one of the hosts to the other. The corn, however, appeared to be much more readily infected than the sorghum with its own smut, since quite high infections were secured over a comparatively wide range of conditions. While comparatively high percentages of infection were obtained with sorghum, using the sorghum smut, yet in general they did not approach those of corn.

The results indicate that the two smuts are distinct in their physiologic capacity for infecting these hosts, although they are not sharply limited to either corn or sorghum. The fact, however, that each smut proved capable of severely infecting its corresponding host while giving very low results from the other, indicates clearly the existence of specialization.

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BROOKLYN, N. Y.

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Explanation of plates

PLATE 21

Head smut on corn. One figure shows a stalk with four smut balls in the axils of the leaves. The other figure shows a smutted ear.

PLATE 22

Head smut on corn. The two figures at the left show ears infected with the smut, the spores still nearly enclosed by the white membrane. The middle figure shows smut balls on the tassel. The figure at the right shows the entire upper portion of the stem converted into a smut ball.

PLATE 23

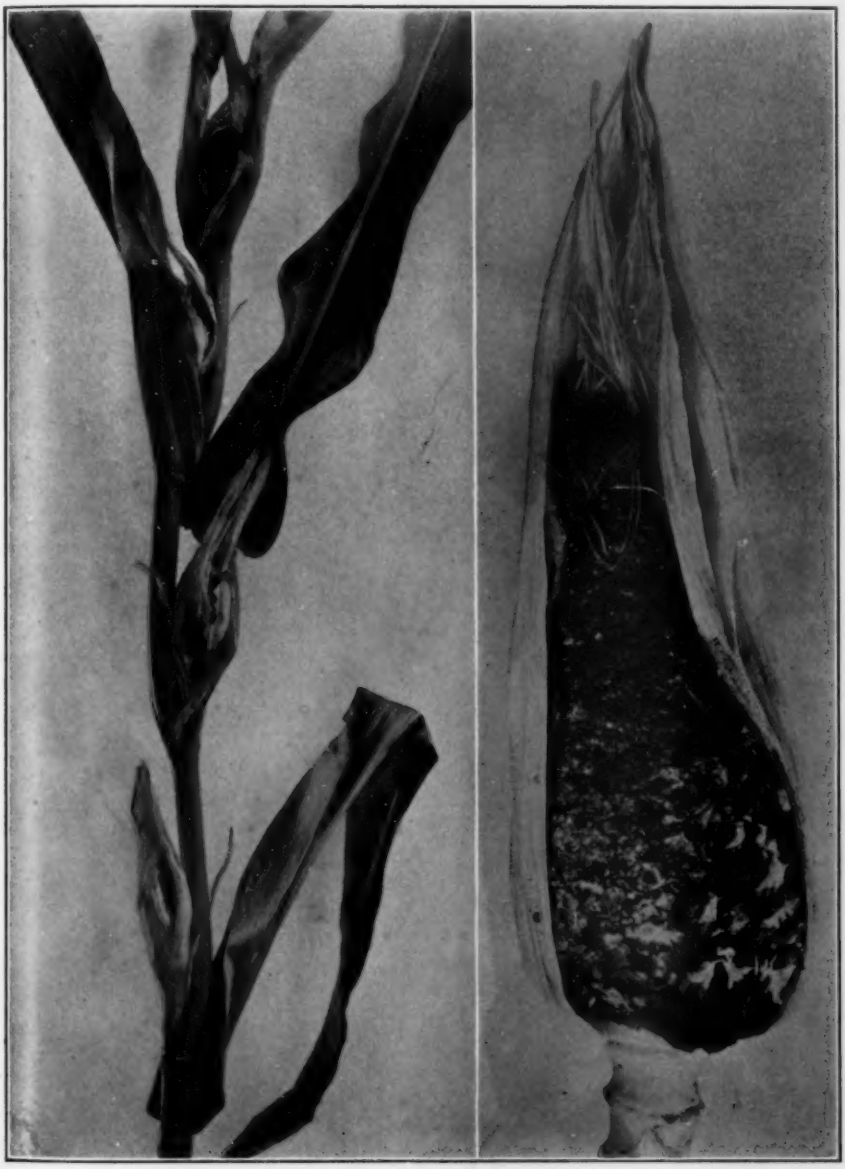
Head smut on corn. The figures show various types of tassel infection.

PLATE 24

Head smut on Red Amber Sorgo. Various types of panicle infection, involving single spikelets, small and larger branches.

PLATE 25

Head smut on Red Amber Sorgo. Practically the entire panicles are involved.



HEAD SMUT ON CORN

UNIV. OF TOR.

HEAD SMUT ON CORN

UNIV. OF MICH.

HEAD SMUT ON CORN

UNIV. OF MICH.

HEAD SMUT ON SORGO

UNIV. OF TEXAS

HEAD SMUT ON SORGO

Additions to the genus Munnozia R. & P.

H. H. Rusby

The genus *Munnozia* was founded by Ruiz and Pavon (Flor. Peruv. Chil. Prod. 108. *pl. 23*. 1794.), who published (Syst. Veg. Fl. Peruv. Chil. 195. 1798.) the four species *corymbosa*, *venossissima*, *lanceolata*, and *trinervis*. Weddell (Chlor. And. 1: 211. 1855.) added *M. sagittata*, and Bentham (Pl. Hartw. 134. 1839.) *M. senecionidis*. De Candolle recognized the genus as valid in the Prodromus, but modern authors have treated it as a section of the now large and heterogeneous group *Liabum*. Bentham (Gen. Plant. 2: 436. 1873.) recognizes nine sections of this genus, most of which will probably come to be recognized as valid genera. The group here treated appears to me to be fully entitled to this consideration.

The figures in Ruiz and Pavon are quite formal, and magnify certain characters, while minimizing others, so that the precise limitations there assigned require some modification, to include the entire natural group. The tridentate inner scales of the involucre are never quite as figured, and this character may be reduced to a mere serration, which, in other species, may disappear altogether. The rays are not always strictly limited to a single series, although I have not found them forming two complete series, in any case. The most important characteristic of the genus is not fully displayed in the figure referred to, and is not fully expressed in the statement "receptacle ciliate." The "cilia" in the species figured (*M. corymbosa*) are in reality narrow paleae or their laciniae, and these lacerate paleae I have found to be an invariable character in the genus, which, as represented by the species here enumerated, possesses the following characters.

Involucre hemispherical or short-campanulate, imbricate, the scales nerved, acute or obtuse, the outer usually successively shorter and broader and less or not at all acute, usually coriaceous, the innermost thin, chartaceous, usually glabrous, often hyaline, entire or more or less serrate or dentate above. Receptacle convex, foveolate, paleaceous, the paleae more or less dentate, laciniate or laciniate-ciliate, and more or less connate. Rays in one, or partly in two series, pistillate, fertile, elongated, nerved, usually minutely 3-dentate, at least the tube more or less

pilose, purplish or yellow (or white?), the style elongated, with long, slender branches. Disk-flowers perfect and fertile, the slender cylindrical tube usually more or less pilose, the throat campanulate or infundibular, the lobes usually long, the style-branches various, usually rather short and stout.

The plants are usually erect shrubs, occasionally climbing or reclining, rarely erect herbs, and are mostly of high altitudes, 8000 feet or higher, in the South American Andes.

In foliage-characters, the genus presents two distinct types. In one, the leaves are coriaceous, green above and densely arachnoid beneath, the margins more or less denticulate, occasionally almost entire, and the form elongated. In the other, they are membranaceous, usually sagittate or hastate, and less, or even not at all arachnoid underneath.

Besides the species named above, the following transfers are proposed.

M. glandulosa *n. comb.*

Liabum glandulosum O. Kuntze. Rev. Gen. 3²: 163. 1898.

M. hirta *n. comb.*

Liabum hirtum O. Kuntze, l. c.

M. giganteum *n. comb.*

Liabum giganteum Rusby, Bull. N. Y. Bot. Gard. 4: 391. 1897.

M. Rusbyi Britton *n. comb.*

Liabum Rusbyi Britton, Bull. Torrey Club 19: 263. 1892.

The following species, so far as I can determine, have not been described.

Munnozia foliosa n. sp. Branches and inflorescence scabrellate, the lower leaf-surfaces white, short-tomentose, the upper dark-green and apparently somewhat purplish, very minutely and sparsely puberulent, with white glistening hairs. Stems tall, stout, striate, purplish-brown, very leafy. Petioles to 2.5 cm. long, stout, scabrous, margined, grooved above, the bases slightly dilated and sub-connate. Blades to 15 cm. long, 5 cm. wide, lanceolate, with blunt or rounded base and acuminate and very acute summit, dentate with very small acute salient teeth and shallow rounded sinuses; thick, the indumentum as stated, the midrib prominent beneath, 2-channeled, the secondaries 10 or 12, with a few lesser intermediate ones, widely spreading, thin, strongly falcate-ascending, the venation coarsely anastomosing. Corymb terminal, small and few-flowered, compound, with few lance-linear or subulate bracts, the peduncles unequal, mostly short and stout. Involucre hemispherical, about 8 mm. high

and nearly 2 cm. broad, the scales in about 4 series, the outer successively shorter, thick and coriaceous, scabrellate, obscurely nerved, broadly ovate, with blunt summit. Innermost scales short-acuminate and acute, obscurely serrate at the top. Receptacle chaffy, its scales narrowly lanceolate, somewhat lacerate at the summit. Rays about 3 cm. long, pilose throughout. Disk corollas pilose or hispid throughout, the tube 6 mm. long, uniformly and narrowly cylindrical, the throat 1.5 to 2 mm. long, the lobes 2 mm. long. Stamens and style long-exserted. Pappus 9 mm. long.

Collected by *M. Bang* near Cochabamba, Bolivia, 1891 (*No. 1195*). Distributed as *Liabum Rusbyi* Britton, but very distinct from that species. Also collected by *Otto Buchtien* at Unduavi, Bolivia, 10,000 ft., Nov. 1900 (*No. 3032*). Buchtien says "A shrub, to 2 meters high, with violet flowers."

Munnozia longifolia n. sp. More or less white-floccose throughout, excepting the upper leaf-surfaces. Stems woody, rather stout, quadrangular, the sides 2-sulcate, reddish-brown underneath the indumentum. Petioles to 2 cm. long, channeled. Blades to 15 by 3 cm., lanceolate, acute at the base and regularly long-acuminate and very acute at the summit, sub-entire or with a few distant minute teeth, thick and coriaceous, dark-green above, with the venation finely channeled, densely white-floccose beneath, the slender secondaries 12 to 14 on each side, strongly falcate and connecting a little way from the margin, the venation loosely and strongly anastomosing. Panicle terminal, very lax, the branches long and very slender, striate, sparsely subulate-bracted, the heads long and slenderly peduncled. Involucre hemispherical, 1.5 cm. broad, the scales in about 6 series, the outer successively shorter, broadly ovate or oval, coriaceous, tomentellate, brown, stoutly nerved, appressed, with recurved or spreading summit and margins, the summit rounded or obtuse. Innermost scales chartaceous, oblanceolate, obtuse, entire or minutely denticulate at the summit. Receptacle paleaceous, the chaff very short, subulate, serrulate, sub-hyaline. Ray-flowers 15 mm. long, pubescent, minutely 3-toothed, strongly 3-nerved, thickish, the style slightly exserted. Disk corolla pubescent, 8 mm. long, the regularly cylindrical tube half the length, the throat infundibular, 1.5 mm. long, the lobes 2.5 mm. long, thin, faintly nerved, the anthers almost equalling them. Pappus 7 mm. long, brown, coarse, unequal.

Collected by *Otto Buchtien* at Unduavi, Bolivia, 3300 meters, Nov. 1910 (*No. 3079*).

"A shrub."

Munnozia chrysanthemoidea n. sp. Minutely puberulent, the lower leaf-surfaces white-floccose. Stems shrubby, rather

stout but weak, brownish-purple, strongly striate or grooved, in the dried state. Petioles to 2 cm. long, stout, margined, the margins minutely and sparsely serrate, the bases abruptly dilated and connate, thick and fleshy. Blades to 12 cm. or more long, and 5 cm. wide, very abruptly contracted into the petiole and with very abruptly short pointed acute or obtusish summit, finely dentate, the teeth triangulate, short, with cartilaginous dark points, the sinuses shallow and rounded; thick and somewhat rigid, the upper surfaces dark-green, the lower closely and densely white-floccose, the venation conspicuous, purplish-brown, the midrib broad, irregularly 3-ribbed, the secondaries 10 or 12 on a side, widely divergent at the base, then strongly falcate-ascending, the venation coarsely and strongly anastomosing. Panicle terminal, many-flowered, large and showy, bracted with miniature foliage-leaves, the peduncles elongated, slender, striate. Involucre hemispherical-campanulate, 1 cm. long, about 1.5 cm. broad, slightly concave at the base. Scales 3-nerved, all appressed, in about 5 series, coriaceous, the outer successively shorter, ovate, the outermost broader than long, with rounded green summit. Inner scales lanceolate, acuminate and acute, serrate toward the summit. Receptacle convex, densely chaffy, the scales narrow, acuminate, lacerate at the summit. Rays 3 cm. long, 3 mm. broad, oblanceolate, obtuse, minutely 3-toothed, 3- or 5- nerved below the middle, coarsely pilose at the base, the tube filiform, 8 mm. long. Exserted portion of style 5 mm. long, cleft nearly half-way. Tube of disk flowers narrowly and uniformly cylindric, 6 mm. long, the throat campanulate, 2 mm. long, pilose, the lobes 3 mm. long, ovate, acutish, 1-nerved. Anthers 3 mm. long, short-sagittate, exserted. Style thick, scabrous, much exceeding the stamens, the branches short and slender. Pappus pale, 1 cm. long, the outer little shorter than the inner.

Collected by *M. Bang* near Mapiri, Bolivia, 10,000 ft. (?), September, 1892, and distributed and published as *Liabum Rusbyi* Britton, from which it differs markedly in the form and proportions of the disk corollas, and in other ways. The plant is apparently a shrub, with handsome purple or rose-colored flowers.

Munnozia Ariste-Josephi n. sp. More or less white-floccose throughout, excepting the upper leaf-surfaces. Stems stout, apparently herbaceous. Petioles to 3 or 4 cm. long, slender. Blades (only upper seen) to 10 × 5 cm., ovate, mostly somewhat inequilateral, not hastate, short-acuminate and acute, irregularly sinnuate-dentate, the teeth broadly triangular, mostly obtuse; membranaceous, thin, dark-green and sparsely and very shortly strigose above, densely white or grey floccose beneath, sub-trinerved, the crooked secondaries about 8 on each side, Panicle ample, very lax, the branches opposite, with long linear

attenuate bracts, the branchlets one-flowered, very slender. Involucre hemispherical, nearly 2 cm. broad, 1 cm. high, the scales in about 6 series, more or less floccose, finely nerved, all about equal, the outer herbaceous, all lanceolate, acuminate and very acute. Receptacle chaffy, the chaff regularly connate into infundibular calyces, with fimbriate and ciliate margins. Ray-flowers purple (?), 2 cm. long, the tube 3 mm., strongly pilose, the style long-exserted, very slender, like its branches. Disk-flowers 8 mm. long, the tube a little more than half, the lobes oblong, short, the style little exserted, the branches stout. Pappus of the disk-flowers 6 mm. long, the outer about two-thirds as long as the inner.

Collected by *Brother Ariste-Joseph*, at Guassia, Colombia, Sept. 1919 (*No. A 455*). The peculiarly connate chaff of the receptacle in this species apparently gives the "foveolate-ciliate" appearance described by Ruiz and Pavon in the type species of the genus.

Munnozia muricata n. sp. Stems coarsely short-pilose, the brachlets hispid with short, stout, divaricate hairs, the upper leaf-surfaces short-strigose, the inferior densely white-floccose. Stems shrubby, stout, but weak, perhaps climbing or reclining, reddish, irregularly angled and sulcate, the branchlets short, erect. Petioles to 3 cm. slender, sub-hispid, dilated at the base and sub-connate. Blades to 7 × 4.5 or 5 cm., triangular-ovate or sub-deltoid, acute, the base truncate, mostly more or less hastate, the basal lobes very small, the margin sinuate-dentate with short and broad triangular teeth, their tips indurated; membranaceous, above deep-green, below white, 3-nerved, the midrib more or less muricate, the venation coarsely and strongly anastomosing, reddish. Panicle small, contracted, the peduncles slender, reddish. Involucre hemispherical, 1 cm. broad, the scales in about 5 series, all ovate, acuminate and acute, the outer successively shorter and more abruptly acuminate, all equally thin and very strongly 5-nerved, brown, sparsely puberulent. Receptacle densely chaffy, the chaff rather long, lanceolate, acuminate and acute, densely lacerate-ciliate. Rays 2 cm. long, strongly 5-nerved, lightly 5-toothed. Disk-flowers 1 cm. long, the tube less than half the length, pubescent, the lobes 2.5 mm. long, the midrib very strong.

Collected by *Otto Buchtien* at Unduavi, Bolivia, 3300 meters, November 1910, (*No. 681*).

Munnozia deltoidea n. sp. (*Liabum hastatum* (Wedd.) Britton, Bull. Torrey Club, **19**: 263.) Through an error in publication, this name was written "hastatum," instead of "sagittatum," based on Weddell's *Munnozia sagittata*, which the plant

very closely resembles, and which it was believed to be. This determination was followed in my publication of *Mr. Bang's No. 670*. In the light of much fuller information regarding this and related species, it now appears that this is distinct from *M. sagittata*, the leaves of which Weddell distinctly says are "not three-nerved, as in *M. venossisima*." So far as the very meagre description of the latter species discloses, our plant is not of that species, and it appears not to have a name. The description follows:

More or less white-floccose, the young stems, petioles, etc., sparsely pilose with short, stout, spreading hairs. Stems shrubby, the branches elongated, crooked and probably climbing or reclining, the branchlets angled and sulcate. Petioles (only the upper seen in the type specimen,) 2 cm. long, very slender, channeled above, dilated and connate or sub-connate at the base, with irregular small foliaceous stipuloid appendages. Blades to 7 cm. long and nearly as broad (the lower ones probably much larger), triangular-hastate, acute, the basal lobes large, triangular, acute, the margin very irregularly sinuate-dentate with triangular acute salient teeth; membranaceous, thin, dark-green and sparsely, almost imperceptibly puberulent above, densely white-floccose beneath, with the slender, reddish venation wholly uncovered, the principal veins 2-sulcate; 3-nerved from the base, 2 or 3 branches spreading into the basal lobes, the secondaries from the midrib about 6 or 8 on each side, crooked, intercommunicating at some distance from the margin, the venation very loosely anastomosing. Inflorescence terminal, sparse, long and slenderly branched, the branches bearing one or two heads. Involucre hemispherical, 1.5 to 2 cm. broad, 8 mm. high, somewhat gray-puberulent, the scales in 4 or 5 series, thickish, 3 or 5-nerved, appressed, the outer successively shorter, obtuse or acutish, the inner becoming acuminate and acute. Rays purple, 2.5 cm. long, the ligule 1.5 cm., strongly 5-nerved, the tube short-pilose, the style shortly exserted, the lobes short and rather stout. Disk-flowers 8 mm. long, pilose, the tube a little more than half, the lobes 2 mm. long, exceeding the stamens, the style puberulent, shortly exserted, the branches short, rather stout. Receptacle densely chaffy, the chaff short and small, ciliate-lacerate.

Besides the collections noted above, of which *Rusby's 1744* is the type, this species was collected by *Buchtien* (*No. 475*) at Unduavi, Bolivia, at 3200 meters. This specimen has leaf-blades to 15 × 10 cm., with much larger teeth, but it agrees perfectly, on dissection.

The species is allied to *M. corymbosa*, *M. muricata* and *M. Ariste-Josephi*.

Munnozia strigulosa n. sp. Grayish-floccose throughout, excepting the upper leaf-surfaces. Stems woody, stout, terete. Petioles to 4 cm. long, stout, channeled above and striate, moderately dilated at the base and sub-connate. Blades to 13 by 4 cm. (exclusive of the basal lobes), lanceolate, long-acuminate and acute, hastate, the basal sinus very shallow and broad, the basal lobes rather small, triangular-lanceolate, acute, widely spreading, the margin very irregularly sinuate-dentate, the teeth small, short, broadly triangular, mostly acute; membranaceous, thin, deep-green and very finely to rather coarsely strigulose above, densely yellowish-gray-floccose beneath, sub-five-nerved, the lowest pair of nerves recurved into the basal lobes, the secondaries 10 or 12 on each side, slender, crooked, the venation partly concealed in the indumentum. Panicle terminal, ample, loosely many-flowered, the branches elongated and slender, the lower in the upper leaf axils, linear-bracted, the bracts few and small. Involucre hemispherical, nearly 2 cm. broad, 8 mm. high, the scales few, in about 4 series, closely imbricated, brown-tomentellate, very strongly nerved or sub-costate, broadly ovate, ciliate, acute or the outermost obtusish and somewhat smaller. Rays yellow, 2 cm. long, the tube 3 mm., puberulent, the very slender style long exserted, its branches long and slender, the ligule faintly 3-nerved. Disk-flowers 8 mm. long, the tube about half the length, pubescent, the throat sub-cylindrical, as long as the tube, the lobes linear, slightly exceeding the stamens, the style little exserted, the branches very short. Pappus nearly equalling the corolla. Receptacle densely chaffy, the chaff short, ciliate-lacerate.

Collected by *F. W. Pennell*, along roadside, on a forested slope of Tequendema, Cundinamarca, Colombia, 2300 to 2400 meters, Sept. 15, 1917 (*No. 1970*). *No. 4432*, from the State of Bolivar, Cordillera Occidental, 2800 to 3100 meters, "a shrub with yellow flowers," is probably a form of the same, although its involucral scales are scarcely acute and are somewhat arachnoid. It is less likely that *No. 7450* belongs to this species. This is "a climbing shrub, with yellow flowers, from Mt. Santa Ana, Cauca, 2800 to 3000 meters, June 29–30, 1922. The base of this leaf is strictly truncate, and scarcely hastate. The base of the throat of the disk-corolla, externally, is strongly and stoutly pilose and the style-branches are longer.

Munnozia attenuata n. sp. White-floccose throughout, excepting the upper leaf-surfaces. Stems woody, slender, purple, striate. Petioles to 1.5 cm. long, narrowly margined, the mar-

gins upcurved, dilated and connate at the base. Blades to 10 by 2 cm., triangular-lanceolate, the base abruptly contracted into the petiole, regularly acuminate from the base to the attenuate summit, the margin sinuate-dentate, the teeth very small, salient; membranaceous, thin, deep-green and glabrous above, densely white-floccose beneath, the slender purple venation not covered, sub-trinerved, the slender crooked secondaries about 10 on each side. Panicle terminal, the lower branches in the axils of the upper leaves, the branches linear-bracted, elongated, slender, erect, mostly 1-flowered. Involucre hemispherical-campanulate, minutely puberulent, the scales in about 6 series, closely imbricate, the outer successively shorter, thick, coriaceous, strongly many-nerved, oval-ovate, obtuse, becoming acutish within. Rays light-yellow, 2 cm. long, the tube 6 mm., pilose, the ligule strongly 5-nerved, the styles very small. Disk-corollas 8 mm. long, the tube nearly half the length, pilose, the throat infundibular, the lobes lanceolate-linear, longer than the throat, the style little exserted, its branches very small. Akene short and broad, hispid, the pappus copious, 6 mm. long. Receptacle sparsely chaffy, the chaff very small, sparingly lacerate, some merely finely dentate, the summits finely attenuate.

Collected by *Rusby and Pennell* in the edge of a bog, at Balsillas, Huila, Colombia, 2000 to 2200 meters, August 3–5, 1917 (*No. 769*).

"A shrub, with light yellow flowers." It appears to be identical with *Lehmann's No. B.T. 1206*, from Ecuador.

Munnozia filipes n. sp. More or less white-floccose throughout, except the upper leaf-surfaces. Stems shrubby, very slender, more or less striate, or irregularly sulcate, the branches much elongated and very slender, bearing solitary heads. Petioles slender, to 3 cm. long, very narrowly margined, the margins upturned, minutely dentate. Blades to 10 × 2.5 cm., lanceolate, long-acuminate and acute, the base more or less truncate and hastate, the basal lobes very small, divaricate, the margin irregularly sinuate-dentate, the teeth very short, broad; membranaceous, above dark-green, roughish, underneath densely white-floccose, the secondaries about 6 or 8 on each side, slender, weak and crooked, connecting at some distance from the margin. Involucre hemispherical, densely white-tomentellate, to 2 cm. broad, the scales in about 6 series, the outer a little smaller, mostly acute, the inner thin and scarious, minutely ciliate toward the summit. Receptacle densely chaffy, the chaff elongated, brown, acuminate and acute, deeply and coarsely lacerate. Rays yellow, 2.5 cm. long, the tube 5 mm. long, slender, puberulent, the ligules strongly 5-nerved, minutely five-toothed, the style long-exserted, its branches long and slender. Disk flowers 8 to

9 mm. long, the tube a little more than half of the length, puberulent, abruptly dilated into the campanulate throat, which is minutely puberulent, 2 mm. long, the lobes lanceolate. Stamens slightly exceeding the lobes, the style long-exserted, pubescent, its branches very short. Akene short and broad, nerved, white puberulent, the brown pappus crooked, 6 mm. long, the outer but little shorter.

Collected by *Rusby and Pennell* in the forest west of Balsillas, Colombia, 2,000 to 2200 meters, Aug. 3–6, 1917 (*No. 911*, the type.) Also *No. 634* from the same place, and *Pennell's No. 7113* from the Cordillera Central, altitude 3000 to 3200 meters, June 17, 1922. Of this, Pennell says "A climbing shrub, with yellow flowers." Its leaves are shorter, ovate, and somewhat cordate, and its inflorescence is much more compact. There are other slight differences in the flower characters, and it may well be found later to be a distinct species.

Munnozia laxiflora n. sp. White-floccose, excepting the upper leaf-surfaces. Stems herbaceous, very slender, widely branching. Petioles to 5 cm. long, channeled, dilated and connate at the base. Blades to 12 × 5 cm., ovate, acute, the base cordate with wide and very shallow sinus, usually very slightly hastate; membranaceous, above deep-green, minutely strigulose, beneath densely white-floccose, the margin finely sinuate-dentate, the secondaries 8 or 10 on each side, slender and weak, at an angle of about 45 degrees, inter-connecting at some distance from the margin. Panicle compound, very large and lax, the bracts lance-linear, the peduncles long and slender. Involucre hemispherical, 2 cm. broad, the scales in 5 or 6 series, tomentose, ovate with rounded summit, becoming acuminate and acutish within, entire, strongly many-nerved, the outer successively shorter. Receptacle strongly chaffy, the chaff elongated, acuminate, lacerate. Ray flowers yellow, 2.5 cm. long, narrow, oblanceolate, strongly 5-nerved, pubescent, the tube very short, hispid, the summit nearly entire. Disk-flowers 1 cm. long, puberulent, the tube half the length, abruptly expanded into the campanulate throat, which is a little shorter than the linear, thin, hyaline lobes. Stamens shorter than the corolla-lobes, the style equalling the lobes, its branches rather short, stout.

Collected by *Pennell and Killip*, in the Cordillera Central, Colombia, July 11–12, 1922, above tree level, 3300 to 3400 meters (*No. 6518*).

Apparently belonging to this species are *Triana's No. 1150* from New Granada and *Sodiro's No. 594*, from the mountains of Alacatzo, Ecuador. This has been called *Liabum sagittatum* by

Schultes-Bipontinus, but this name cannot obtain under *Munnozia*, as it is preoccuppied. *Pennell's 3154*, a tall herb from the Murillo Road, Tolima, is identical with Triana's plant.

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Notes on Fabaceae—IX

PER AXEL RYDBERG

HAMOSA (CONTINUED)

5. LEPTOCARPAE

This group was proposed by Jones as a section of *Astragalus*. It constituted a part of Gray's section MICRANTHI. Evidently Dr. Gray named his section from *Astragalus micranthus* Nuttall, which is the same as *A. Nuttallianus*. In dividing the section therefore, Jones applied the name MICRANTHI to the wrong part of the section when he used it for the perennial Mexican species. He should have applied it to this group. As the name *A. micranthus* Nuttall is a homonym, however, it is better not to use a sectional or group name based on the same, and I have abandoned the name MICRANTHI altogether.

The group is characterized by the annual habit, the few-flowered inflorescence, the small or rarely middle-sized flowers, the narrow pod—in the typical species strongly flattened—and the comparatively short calyx-tube often not longer than the teeth.

Calyx black-hairy; pod little or not at all compressed; calyx-teeth shorter than the tube.
- Pod glabrous, less than 2 cm. long.
  - Leaflets cuneate or oblong-cuneate, truncate or retuse at the apex, less than 8 mm. long. — 22. *H. Bruceae*
  - Leaflets linear, acute, 1–1.5 cm. long. — 23. *H. Kelloggiana*
- Pod finely strigose.
  - Leaflets usually cuneate or oblong and retuse at the apex.
    - Pod 1–1.5 cm. long, slightly arcuate. — 21. *H. tenera*
    - Pod about 3 cm. long or more, strongly arcuate. — 25. *H. Rattani*
  - Leaflets linear, acute; pod about 2.5 cm. long, moderately arcuate. — 24. *H. rattanoides*

Calyx white-hairy.
- Pod glabrous.
  - Leaflets retuse or truncate at the apex.
    - Pod about 5 mm. wide, arcuate at the base; corolla about 12 mm. long. — 26. *H. Lindheimeri*
    - Pod about 3 mm. wide or less; corolla 10 mm. long or less.
      - Pod straight; corolla 10 mm. long. — 27. *H. leptocarpa*

Pod more or less arcuate; corolla 5–8 mm. long.	
Pod abruptly acute; plant green; stipules lanceolate or lance-subulate.	
Calyx-teeth longer than the tube; pod 3 mm. broad, strongly arched at the base; plant erect or ascending.	28. *H. Nuttalliana*
Calyx-teeth shorter than the tube; pod 1.5–2 mm. wide, equally arched throughout; plant decumbent or prostrate.	29. *H. leptocarpoides*
Pod gradually acute, equally arched throughout; plant canescent, decumbent; stipules ovate.	30. *H. montereyensis*
Leaflets linear to oblong, acute or obtuse.	
Corolla about 1 cm. long; plant green; pod 2.5–3 cm. long.	31. *H. macilenta*
Corolla 5–8 mm. long; plant canescent; pod 2 cm. long or less.	
Pod completely 2-celled.	
Leaflets 7–11, those of the lower leaves oval to oblong.	
Pubescence appressed.	32. *H. Emoryana*
Pubescence spreading.	33. *H. Davisiana*
Leaflets 3–7, all linear or linear-oblanceolate.	34. *H. subuniflora*
Pod with only partial partition.	35. *H. imperfecta*
Pod strigose; inflorescence sub-capitate, 1–5-flowered.	
Leaflets oval to linear, acute to rounded at the apex.	36. *H. austrina*
Leaflets of the lower leaves very short, cuneate, often retuse at the apex.	37. *H. pertenuis*

21. **Hamosa tenera** (A. Gray) Rydb. *Astragalus tener* A. Gray, Proc. Am. Acad. **6**: 206. 1864. The type was collected by Douglas, and first published as *Phaca astragalina* β by Hooker & Arnott. Torrey & Gray referred the specimens doubtfully to *A. leptocarpus*. When Gray described the species the fruit was unknown and he associated it with *A. Breweri*. He also thought that *A. Hypoglottis strigosa* Kellogg was the same. See under *H. Kelloggiana* below. Watson transferred the species to the section MICRANTHI and placed it after *A. atratus* and *A. obscurus*. Jones in his Revision described the pod of *A. tener* as being 'nigrescent when young.' If he had used the word 'canescent' he would have come much nearer for the hairs are

white or ash-colored. If he meant by 'nigrescent' inclined to turn black in drying, his statement may be considered correct, though ambiguous. *Astragalus pauperculus* Greene is apparently the same; so also *A. Titi* Eastwood.

CALIFORNIA: *Douglas; Kellogg & Harford 190; 192;* Los Angeles County, *Abrams 3251;* Solidad, *Jones 47, 3155;* Santa Monica, *Hasse,* in 1890; Contra Costa County, *Eastwood 3818;* Butte County, *Mrs. Bruce 2078;* San Luis Obispo County, *Summers 13;* Alameda, *Greene* in 1891; Oakland, *Brewer 2573;* San Diego, *Jones 3152.*

22. **Hamosa Bruceae** (M. E. Jones) Rydberg. *Astragalus tener Bruceae* M. E. Jones, Rev. Astrag. 268. 1923. This is related to *H. tenera,* but differs in the broader, usually cuneate leaflets, and the deeper more curved and glabrous pod.

CALIFORNIA: Butte County, *Mrs. Bruce 2430; Heller 11286;* Byron, *Biolette,* in 1892.

23. **Hamosa Kelloggiana** Rydb. sp. nov. *Astragalus Hypoglottis strigosa* Kellogg, Proc. Calif. Acad. **2**: 115. 1861. Slender annual; stem glabrous or sparingly strigose, 1–2 dm. high, branched at the base; leaves 5–6 cm. long, ascending; stipules lance-deltoid, about 3 mm. long; leaflets 5–13, those of the lower leaves oblong or cuneate, 1 cm. long or less, those of the other leaves linear, 1–2 cm. long, acute or obtuse, 1–2 mm. wide, strigose beneath; peduncles 4–6 cm. long; racemes very short, 4–7-flowered; bracts lanceolate, 1 mm. long; calyx black-hairy, the tube 2 mm. long, the teeth lance-subulate, 1.5 mm. long; corolla bluish-purple, striate, 8 mm. long, similar to that of *H. tenera;* pod about 1.5 cm. long, arcuate, lunate, glabrous, 3 mm. wide and 2.5 mm. thick, cordate in cross-section.

The species is related to the two preceeding on one hand, and to the next on the other. It differs from *H. tener* in the narrow leaflets and the more arched and more compressed glabrous pod, tapering gradually at both ends; from *H. Bruceae* in the narrow leaflets, the narrower and not mottled pod, and the more numerous flowers; and from *H. rattanoides* in the shorter and glabrous pod. It is evidently the same as the plant described (at least mainly so) and figured by Kellogg as *Astragalus Hypoglottis strigosa.* His illustration consists of the drawing of a whole plant and a single leaf. The whole plant evidently illustrates this plant and he describes the pod as glabrous. The leaf resembles that of *H. tenera* the leaflets being linear-cuneate and slightly

retuse as in *H. tenera*. In his descriptions he states that individuals are found either with linear or cuneate leaflets or with both. The leaf-form may not be constant, though I have not seen any evidence that it is not. At any rate the pod is not that of the typical *H. tenera* but nearer to that of *H. Bruceae*. Sheldon adopted the name *strigosus* as specific, following the Madison amendment of the Rochester Code, but applied it to *H. tenera*.

CALIFORNIA: Vallejo May 15, 1874, *Greene* (type in Gray Herbarium); Alameda County *Michener & Bioletti*, in 1891; Contra Costa County; *Eastwood 3818;* Oakland, *Holder 2573;* Mt. Diabolo, *Gibbons*, in 1872; *Kellogg & Hartford 192;* San Francisco, *Vasey*, in 1875; Alviso, *Williamson*.

24. **Hamosa rattanoides** (M. E. Jones) Rydb. *Astragalus tener rattanoides* M. E. Jones, Rev. Astrag. 269. 1923. This is related to *H. Rattani* differing in the longer pubescent pod and stands in the same relation to it as *A. Kelloggiana* does to *A. Brucei*. The following specimens are recorded:

CALIFORNIA: Mount Eden, *Brandegee* (type); Woodland, *Blankinship*, May 20 and April 8 (mainly) 1893); Contra Costa County, *H. Edwards*, in 1895; without locality, *Bridges 77;* Aloiso, *R. J. Smith*, in 1915; Vaccaville, *Jepson*, in 1892.

25. **Hamosa Rattani** (A. Gray) Rydb. *Astragalus Rattani* A. Gray. Proc. Am. Acad. **19:** 75. 1883. This differs from *H. tenera* in the more robust habit, usually broader leaflets and the long pod, 3–4 cm. long, strongly arched, very narrow, and gradually tapering at each end. *A. clarianus* Jepson seems to be the same. The type of *A. clarianus* has not been seen by me, but Jeppson's description and illustration fits *H. Rattani* as I understand it and as described and figured by Jones.

CALIFORNIA: Sacramento River, Butte County, *Mrs. Bruce 2432;* Humboldt County, *Rattan*, in 1883; *Goodard 6124;* Mendocino County, *Rattan 10; Purpus*, in 1889; *Blankinship* in 1893; Yolo Co., *Ferris 706;* Humboldt Co., *Tracy 4241*.

26. HAMOSA LINDHEIMERI (A. Gray) Rydb. This differs from the rest of the annual species of *Hamosa* by its large flowers, broad glabrous pod, and stouter habit. Jones (Rev. Astrag. 267. 1923) claims, for what reason I do not know, that *Astragalus recticarpus* Wood (Bot. Gaz. **3:** 50. Je 1878) is the same. Wood's description does not fit it. Furthermore Wood himself (Bot.

Gaz. 3: 70. Au 1878) two months later made the following correction: '*Astragalus recticarpus*. This plant is a form of *Indigofera leptosepala* Nutt., with very narrow leaflets.'

TEXAS: *Wright*, in 1850; Brown County, *Reverchon* [Curtiss No.] *601*;* Northwestern plains, *Pringle*, in 1883; San Antonio, *Thurber*, in 1853; New Braunfels, *Lindheimer 258, 442, 746, 747;* without locality, *Hayes, Nealey 91;* Dawson, *Reverchon 3761; Young*, in 1914; Galveston, *Tracy 9104, 9111;* Austin, *E. Hall 148*, in part; without locality, *Pope, Bray 449, Wright, Thurber, Young 41;* Minerva, *Reverchon 3759;* Brown Co., *239*.

27. HAMOSA LEPTOCARPA (T. & G.) Rydb. This resembles *H. Nuttallii* closely, but the pod is straight, the flowers are larger and the inflorescence is more distinctly racemose.

TEXAS: Without locality, *Drummond I;* Rio Brazos, *Drummond*, in 1850; Sabine River, *Leavenworth;* Galveston, *E. Meyer;* Dallas County, *Reverchon* (Curtiss No.) *601**, 241;* Nueces County, *Heller 1443;* Tarrant County, *Ruth 356;* Corpus Cristi, *Tracy 9104;* Eagle Pass, *Hanson 366;* Marshall, *Earle 5;* Seely, *Plank*, in 1894; Tyler County, *Nealey 26;* Hempstead, *E. Hall 147;* San Marcos, *Stanfield*, in 1897; locality not recorded, *Lindheimer 46; Reverchon 1637; Berlandier 361; Havard 181, 182;* Galveston, *Tracy 9111;* Bastrop, *Tharp 828;* Industry, *Wurzlow 32*, in part; Brazos, *Nealley 70*.—ARKANSAS: *Leavenworth*.—OKLAHOMA: Wervoka, *Carleton 101*.

28. HAMOSA NUTTALLIANA (DC) Rydb. was based on *Astragalus Nuttallianus* DC., a substitute for the untenable *A. micranthus* Nutt. The type of the latter was collected on the Red River, Arkansas, and was described as having glabrous pod and emarginate leaflets. It is evident that Jones had misinterpreted this species as he describes the pod as 'pubescent except when fully ripe at times' and gives the distribution as 'common on the Pacific Coast to the plains of Colorado throughout the Great Basin and southward to central Mexico.' This would apply better to *Hamosa austrina* Small. His varieties *A. Nuttallianus enneajugus* and *A. Nuttallii quadrilateralis* represent the true *H. Nuttallii*. The former is merely a more luxuriant form; the latter is practically the same, only that the pods are well mature, more turgid and more or less 4-angled; a similar plant was collected by Dr. Leavenworth near Fort Towson,

Arkansas. Only one specimen of *H. Nuttalliana* has been seen from the west side of the continental divide, namely one collected by Crandall in 1898, at Palisades, Delta County, Colorado. The distribution of the species is limited to Oklahoma, Texas and western Arkansas.

29. **Hamosa leptocarpoides** (M. E. Jones) Rydb. sp. nov. *Astragalus Nuttallianus leptocarpoides* M. E. Jones, Contr. W. Bot. **8:** 22. 1898. This resembles a small *H. Nuttalliana*, but the pod is more slender, and evenly but slightly curved throughout (not as in *H. Nuttalliana* more strongly curved near the base) and in the shorter calyx-lobes. In this respect it resembles more *H. leptocarpa*, but the flowers are much smaller, and the pod arcuate. The only specimens seen are those of the type collection, collected by Engelmann on Galveston Island (Mo. Bot. Gard.).

30. **Hamosa montereyensis** Rydb. sp. nov. Annual; stem branched at the base, decumbent, strigose, 1–2 cm. long; leaves 2–3 cm. long, spreading; stipules ovate, about 4 mm. long, ciliate; leaflets 13–19, oblong, 4–7 mm. long, about 2 mm. wide, emarginate or truncate at the apex, cuneate at the base, glabrous above, grayish-strigose beneath, rather thick; peduncle 3–5 cm. long; racemes very short, 4–8-flowered; bracts lanceolate, 1–2 mm. long; calyx strigose, the tube 2 mm. long; teeth lance-subulate, 2 mm. long; corolla purplish, 7–8 mm. long; banner broadly obovate, notched at the apex; wings about as long, the blade broadly oblanceolate, obtuse, with a reflexed auricle; keel-petals shorter, broadly lunate, abruptly incurved at the obtuse apex; pod glabrous, slightly and evenly arcuate, acute at each end, 1–1.5 cm. long, 3 mm. wide.

This is related to *H. Nuttalliana* but is spreading on the ground, more canescent, with short leaves and thick leaflets, and different pods.

The type was collected at Monterey, Nuevo León, February 1880, *Palmer 237* (Gray Herbarium).

31. HAMOSA MACILENTA Small is related to *H. leptocarpa* and *H. Nuttalliana*, but differs from both in the non-retuse leaflets. The corolla is as large as that of the former, and the raceme more or less elongate, but the pod is distinctly arcuate below, as in *H. Nuttalliana*. Jones has reported specimens hybrid between the two, but I do not think it is of hybrid origin. Jones regarded this as a synonym of *Astragalus leptocarpus*.

TEXAS: Blanco River, *Wright;* without given locality, *Reverchon 1637; Mexican Boundary Survey 254a;* Gillepie County, *Jermy 263.—Nuevo León:* Monterey, *Canby 77.*—COAHUILA: Diaz, Rio Grand Valley, *Pringle 9026.*

32. **Hamosa Emoryana** Rydb. n. sp. *Astragalus Nuttallianus* var. [no. 1.] A. Gray, Pl. Wright. **2:** 43. 1853. This species was first collected by C. Wright in 1850 (no. *156*) and Dr. Gray gave a short description (see Pl. Wright. **1:** 52. 1852). As this number represents a depauperate form, I have not made it the type. The same form was also collected by Wright in 1852 (no. *1001*, in part, the other part being depauperate specimens of *H. austrina*). In both the Gray Herbarium and the Torrey Herbarium the specimens are mounted on the same sheet. Gray in Plantae Wrightianae **2:** 43 gives five localities, and the two sets might not have been collected at the same locality. Wright also collected well developed specimens the same year at El Paso (no. *1359*). This number as represented in the Torrey Herbarium I have taken as the type. Gray in his description indicates that some of the specimens have hairy and some glabrous fruit. In the Torrey Herbarium only glabrous-fruited specimens are represented.

Astragalus Nuttallianus canescens T. & G. might be the same. Where this name was first mentioned in print (Pacific R. R. Rep. **2:** 163. 1855) there was no description, only a reference to 'Gray Pl. Wright.,' without page or specimen number. This may refer to four of Wright's numbers, viz. *156*, *1359*, *1001*, and *1360*, all of which have a short description.

Parry (Am. Nat. **9:** 270. 1875) simply enumerated *A. Nuttallianus canescens.* His specimen no. *50* represents *A. austrina* Small. So does *Wright 1001* and *1360* in part. The name *A. Nuttallianus canescens* should therefore be cited to S. Watson's Bibl. Index 198, 1878, as the author refers back to the published but nameless description in Plantae Wrightianae both in volume 1 and volume 2. As Watson admits the var. *trichocarpus*, it may be inferred that the var. *canescens* should apply to the glabrous fruited plant, but technically it refers to both, and the name *canescens* is preoccupied as specific in the genus *Astragalus* and therefore it is best not to use it in *Hamosa.*

Hamosa Emoryana has been confused with *H. Nuttalliana*, *H. macilenta* and *H. austrina.* From the first it differs in the

leaflets, which are shorter, hairy on both sides, never emarginate, and by the pod which is more arched. It has the leaf-form of *H. macilenta*, though the leaflets are smaller, but is distinguished by the other characters and by the much smaller flowers. It is harder to distinguish it from *H. austrina* (*A. Nuttalianus trichocarpus*), the main difference being the glabrous fruit, which is usually more curved; the leaflets are usually shorter. The following specimens belong here:

TEXAS: El Paso, *Vasey*, in 1881; *E. Hall*, in 1872; *Wright 1359, 1001*, in part (depauperate); Frontera and Eagle Pass, *Mexican Boundary Survey 288*, in part; Sommerville, *Reverchon* (Curtis no.) *601**;* west of Pecos, *Tracy & Earle 418;* Shafton, *Hanson 557;* Davis Mountains, *Earle & Tracy 190;* Bracket, *Canby 74;* Tom Green Co., *Tweedy 61;* Cow House Creek, *Reverchon 1368.*—NEW MEXICO: *Wright 156;* Capitan, *Earle 632;* Tunitcha Mountains, *Standley 7835;* Organ Mountains, *Wooton*, in 1903 and 1905.—ARIZONA: Tucson, *Griffiths 2408, 3479; Toumey*, in 1894, 1895, and 1896; Red Rock, *W. F. Parish* in 1884; without locality, *Palmer 507;* Kayenta, *Wetherill;* Tucson, *Harris 1428;* Carrizo Mountains, *Standley 7461;* Verde River, *Smart 93.*—CALIFORNIA: Paraminth Mountains; *Coville & Funston 513.*—CHIHUAHUA: near the City, *Palmer 171*, in 1908; *Pringle 276*, in 1885.

33. **Hamosa Davisiana** (Greene) Rydb. sp. nov. *Astragalus Davisianus* Greene, Ms. in herb. Annual or perhaps perennial; stem branched at the base, decumbent, 1–1.5 dm. long, terete, hoary-canescent; leaves 2–3 cm. long, spreading; stipules ovate, acuminate, 4 mm. long; leaflets 11–15, oval or elliptic, 2–5 mm. long, hoary-canescent with ascending or spreading hairs; peduncles 1–3 cm. long; bracts lance-subulate about 2 mm. long; calyx hirsute, the tube 2 mm. long, the teeth subulate, nearly as long; corolla apparently white, 7–8 mm. long, similar to that of *H. Nuttalliana;* pod regularly arcuate, 12–18 mm. long, 2.5 mm. wide and thick, glabrous, strongly reticulate, obcordate in cross-section.

This species is related to *H. Emoryana* but distinguished by the hoary loose pubescence and the strongly reticulate pod. The type was collected in the Davis Mountains, Texas, April 28, 1902, *Tracy & Earle 329.* (Herb. N. Y. Bot. Gard.)

34. **Hamosa subuniflora** (Greene) Rydb. *Astragalus subuniflorus* Greene, Leaflets **2:** 42. 1910. This is closely related to

the preceding, differing in the fewer (5–9), longer, and narrower leaflets and few- (1–3-) flowered racemes. The corollas are apparently white. It is known only from Tehuican, Puebla, *Pringle 6678* (type); *Arsène 3622*.

35. **Hamosa imperfecta** Rydberg, sp. nov. Annual; stem branched at the base, decumbent, 2–3 dm. long, very sparingly strigose, straw-colored, terete; leaves 2–4 cm. long; stipules lanceolate, 2 mm. long; leaflets lance-oblong or lance-linear, acute at each end, strigose beneath, glabrate above, 5–10 mm. long; peduncles 3–8 cm. long; racemes usually 2-flowered; bract subulate, 1 mm. long; calyx strigose, often partly with black hairs; the tube less than 2 mm. long, the teeth subulate, of about the same length; corolla apparently white, 5 mm. long; pod arcuate especially at the base, glabrous, 15–18 mm. long, 2 mm. broad, and 3 mm. deep, slightly sulcate on the lower suture, only partially 2-celled, the partition very narrow; seeds 2.5 mm. long.

This resembles a slender *H. Emoryana* but the pod is imperfectly 2-celled and the calyx often bear black hairs.

NEVADA: Rhyolite, Nye County, May 17, 1909, *Heller 9637*, (type, herb. N. Y. Bot. Gard.).—ARIZONA: Yucca, *M. E. Jones*, in 1887.—LOWER CALIFORNIA: Rosario, *Orcutt 1349*.

36. HAMOSA AUSTRINA Small. This was first collected by Drummond in Texas and described by Torrey and Gray as *Astragalus Nuttallianus trichocarpus*. Young in her Flora of Texas raised it to specific rank, but evidently confused it partly with *H. Emoryana*, as she described it as having glabrous fruit. The name *Astragalus trichocarpus* was preoccupied by *A. trichocarpus* Wallich of 1868. Small independently described the plant as *H. austrina*, the type being *Thurber 417* from Rio Fronteras. On the type sheet the name of the state is not give. As there was at the time of the Mexican Boundary Survey a Frontera above El Paso in Texas, Dr. Small presumed that it was from there. A duplicate of *Thurber 417*, however, gives the locality as Fronteras, Sonora, Mexico. The plant is very common in Texas and Arizona but the range extends from Oklahoma to Utah, Lower California and Durango.

37. **Hamosa pertenuis** (Greene) Rydb. *Astragalus pertenuis* Greene, Leaflets 2: 42. 1910. This is related to *H. austrina*, having the hairy pod (though smaller and often imperfectly 2-celled) of that species, but it is much more slender, decumbent, and the leaflets of the basal leaves are decidedly cuneate and

deeply notched. It was first described by Vasey & Rose (Contr. U. S. Nat. Herb. **1**: 15. 1893) as *Astragalus* sp., stating that they had distributed it under the name *A. cedrocensis* but that "Mr. Watson thinks it is *A. Nuttallanus*." Jones made it a variety of *A. Nuttallianus*. The latter described the pods as "smooth." In all specimens seen they are strigulose and reticulate.

LOWER CALIFORNIA: Cedros Island, *Palmer 692;* Los Angeles Bay, *Palmer 571;* San Jorge, *Brandegee*, in 1889; 'northern Lower California,' *Orcutt*, in 1886; Cape Region, *Brandegee*, in 1892.—CALIFORNIA: Goffs, San Bernadino Co., *Parish 9656*.

6. ACUTIROSTRES

This group consists of two species, which have been referred to *Oxytropis* or *Aragallus*. Notwithstanding the fact that the keel is produced into a short beak, they evidently do not belong to that genus, but are in all other respects good species of *Hamosa*. There are several species of *Homalobus* and *Hamosa* in which the keel is acute. In the present two species it is acuminate, but the beak is not porrect as in most species of *Aragallus*.

Calyx-lobes much shorter than the tube; leaflets not retuse. 38. *H. nothoxys*

Calyx-lobes equaling or longer than the tube; leaflets retuse. 39. *H. acutirostris*

38. **Hamosa nothoxys** (A. Gray) Rydb. *Astragalus nothoxys* A. Gray, Proc. Am. Acad. **6**: 232. 1864. This is evidently related to *H. arizonica*, *H. Coahuilae*, and *H. bernadina*, differing (besides the beak) in the leaflets, which are glabrous above and broader; the pod is nearly erect but longer than in *H. Coahuilae*. The plant was originally described as an annual and evidently blooms the first year, but some specimens as for instance those collected by Pringle in the Santa Catalina Mountains are without doubt perennial.

ARIZONA: Tucson Range, *Griffiths 2541;* Sabinio Cañon, *Griffiths 2581;* Apache Pass, *Greene 1072*, in part (fruit); Santa Catalina Mountains, *Pringle*, in 1881; Patagonia Mountains, *Tidestrom 776;* Santa Rita Mountains, *808*.—SONORA: *Thurber*, in 1851; San Luis Mountains and Guadaloupe Canon, *E. K. Smith*.—CHIHIAHUA: Puerta di San Diego, *Hartman 622, 630*.

39. **Hamosa acutirostris** (S. Wats.) Rydb. *Astragalus acutirostris* S. Wats. Proc. Am. Acad. **20:** 360. 1885. Notwithstanding the beaked keel, this species is a true *Hamosa* related to the LEPTOCARPAE. Greene redescribed this species under the name of *Astragalus streptopus*. Jones has transferred it to *Oxytropis* and Heller to *Aragallus*, on account of the beaked keel.

The general habit is somewhat like that of *H. Nuttallianus*, the leaflets being retuse as in that species, but the racemes is more elongate, the calyx has some black hairs, the pods are more acute at each end and strigulose and the pubescence of the leaves is more spreading.

CALIFORNIA: Mojave Desert, *Curran*, in 1884, *Parish 1276*, *Lemmon*, in 1884, Darwin, *Jones*.

7. HARTWEGIANAE

The group is characterized by a dense raceme of usually many small flowers. The pod is small, short and rather broad, more or less triquetrous, inverted V-shaped and Y-shaped in cross-section, lanceolate and gradually acute in outline.

Plants about 3 dm. high, erect; raceme elongate.
- Corolla purple, 7–8 mm. long. — 40. *H. militaris*
- Corolla white or ochroleucous.
  - Pod pubescent.
    - Calyx black-hairy.
      - Pod 7–9 mm. long, strigose.
        - Pod black-hairy; leaflets linear. — 41. *H. Saltonis*
        - Pod white-hairy; leaflets oblong. — 42. *H. Goldmani*
      - Pod about 1 cm. long, strigulose. — 43. *H. hidalgensis*
    - Calyx white-hairy; pod 10–12 mm. long.
      - Corolla 7–8 mm. long. — 44. *H. Hartwegii*
      - Corolla 4–5 mm. long. — 45. *H. vaccarum*
  - Pod glabrous.
    - Corolla pink-purple. — 48. *H. Esperanzae*
    - Corolla white. — 46. *H. Clevelandi*

Plant 1–2 dm. high, decumbent at the base.
- Plant silvery canescent; raceme elongate. — 47. *H. hypoleuca*
- Plant merely strigose, the leaves glabrate above, raceme short.
  - Corolla less than 1 cm. long; pod lance-oblong.
    - Pod glabrous; corolla 8 mm. long, pink-purple. — 48. *H. Esperanzae*
    - Pod strigose.
      - Leaflets linear.
        - Calyx white-hairy, the teeth shorter than the tube. — 49. *H. parva*

Calyx black-hairy, the teeth fully equaling the tube.	50. *H. asprella*
Leaflets obovate.	51. *H. hypoxyla*
Corolla more than 1 cm. long, white; plant densely cespitose, prostrate; pod broadly oblong.	52. *H. Pringlei*

40. **Hamosa militaris** (M. E. Jones) Rydb. *Astragalus militaris* M. E. Jones, Rev. Astrag. 278. 1923. Jones in describing this species evidently had a mixture before him. In his key he described the pod as being 'smooth.' By 'smooth,' he evidently meant glabrous, for he contrasted 'smooth' against 'loosely pubescent' in *A. Hartwegii* and 'nigrescent' (meaning having a tendency to be black-hairy) in *A. Saltonis*. The type of *A. militaris* in Jones herbarium (now at Pomona College) has strigulose pods. He also cited two numbers, *Pringle 1586* and *Palmer 441*. The character 'pod smooth' might have been taken from the former, which is not at hand at present, but apparently belongs to *H. esperanzae*. *Palmer 441* belongs to *H. Goldmani* and has strigulose pod. *H. militaris* is related to *H. Hartwegii*, differing in the purple corolla and the strigulose pod, the hairs being much shorter.

CHIHUAHUA: Soldier Canyon, *Jones*, in 1903 (type); Colonia Diaz, *E. W. Nelson 6448*.—SAN LUIS PATOSI: Media Luna, *Palmer 65* and *81*, Guascana, *Purpus 5195*.

41. **Hamosa Saltonis** (M. E. Jones) Rydb. *Astragalus Saltonis* M. E. Jones, Rev. Astrag. 279. 1923. The species was described from specimens collected at Salto de Aqua, State of Mexico, *Purpus 1751*. As I understand the species, it is closely related to *H. Hartwegii*, differing in the black-hairy calyx, the shorter and plumper, less arcuate, and black-hairy pod.

PUEBLA: Rancho Pasado, near the city of Puebla, *Nicolas 105* (distributed by Arsène). Mayorazzo, *Arsène 1429;* San Juan, *207*.—HIDALGO: Pachuca, *Rose, Painter & Rose 8811*.—MEXICO (State and Federal District): *Rose & Painter 7290;* Tacubaya, *Bourgeau 337;* Mixode, *Arsène 10018*.

42. **Hamosa Goldmani** (M. E. Jones) Rydb. *Astragalus Goldmani* M. E. Jones, Rev. Astrag. 281. 1923. This species is more closely related to *H. vaccarum*, differing in the black-hairy calyx, and the shorter and plumper pod.

CHIHUAHUA: Parral, *Goldman 119* (type); Guerrero, *Pringle*

1217 (?, with longer pod).—DURANGO; Ramos, *E. W. Nelson 4708;* Santiago Papasquiaro, *Palmer 441*, in part; Otinapa, *Palmer 395*.

43. **Hamosa hidalgensis** Rydb. sp. nov. Perennial; stem 4–6 dm. high, striate, glabrous or minutely strigulose; leaves 6–10 cm. long, spreading; stipules deltoid, 3–4 mm. long, distinct; leaflets 21–29, oblong, 10–20 mm. long, 2–4 mm. wide, glabrous above, strigulose beneath, truncate, rounded, or, retuse at the apex; raceme 10–15 cm. long; rachis black-hairy; bracts lanceolate, 2 mm. long; flowers reflexed; calyx black-hairy, the tube 2 mm. long, the teeth lanceolate, 1 mm. long; corolla white, about 6 mm. long; banner obovate, strongly arcuate, retuse at the apex; wings somewhat shorter, the blade broadly elliptic; wing-petals still shorter, the blade broadly lunate, rounded at the apex; pod linear-oblong, arcuate, about 12 mm. long, 4 mm. wide, and 2.5 mm. thick, acute at each end, minutely strigulose, broadly cordate in cross-section.

This is closely related to *H. Hartwegii*, but differs in the smaller corolla, and very short pubescence, which is black on the flower-rachis and calyx. Type *Pringle 9720* (herb. N. Y. Bot. Gard.) was collected at Dublan, Hidalgo, September 19, 1902. Besides this *Rose 2757* from Jacatecas may be referred here.

44. **Hamosa Hartwegii** (Benth.) Rydb. *Astragalus Hartwegii* Benth. Pl. Hart W. 10. 1839. The type of *Astragalus Hartwegii* came from Aguascalientes. It is the most widely distributed species of the group. Jones describes the calyx as being 'nigrescent,' an expression which is rather ambiguous. The original meaning is 'growing black' but it is often used as 'inclined to be blackish,' whether it applies to the calyx itself or its hairs. In related species he has evidently used the expression as referring to the hairs. Neither in a duplicate of the type in the Gray Herbarium, nor in most of the specimens regarded by the writer as typical, there is any trace of black hairs either on the calyx or the fruit. In these the hairs on both are white and rather loose. The corolla in the type was apparently white or ochroleucous (so described in the original) and about 7 mm. long.

AGUASCALIENTES: *Hartweg 53*.—HIDALGO: *Rose & Painter 8306*.—MEXICO (Federal District): San Barja, *Arsène 10990;* Guadalupe, *Bourgeau 483*.—DURANGO: Near the City, *Palmer 290;* Tepehuanes, *Palmer 278*.—CHIHUAHUA: Santa Eulalia Mountains, *Pringle 528;* Bolson de Mapimi, *Gregg;* Guerrero,

Pringle 1217.—COAHUILA: San Lorenzo de Laguna, *Palmer 235.*—SONORA: El Padrero, *Schott;* Los Nogales, *E. K. Smith.*

45. **Hamosa vaccarum** (A. Gray) Rydb. *Astragalus vaccarum* A. Gray Pl. Wright. **2:** 43. 1853. This is closely related to the preceding, differing in the smaller ochroleucous corolla and narrower pod; it maybe not distinct.

NEW MEXICO: Ojo de Vaca, *Wright 1002* (type); *Thurber 1051.*—ARIZONA: Huachuca Mountains, *Lemmon 2658.*—DURANGO: Santiago Papasquiaro, *Palmer 441,* in part;—CHIHUAHUA; *E. W. Nelson, 4828.*

46. **Hamosa Clevelandi** (Greene) Rydb. *Astragalus Clevelandi* Greene, Bull. Torrey Club. **9:** 121. 1882. This resembles closely *H. vaccarum,* differing mainly in the glabrous pod. The type came from Lake County, California, collected by Cleveland.

CALIFORNIA: Mount St. Helena, Napa County; Greene in 1883; Hot Springs, Lake County, *Abrams 6269.*

47. **Hamosa hypoleuca** (Schauer) Rydb. *Astragalus hypoleucus* Schauer, Linnaea **20:** 747. 1847. This species is also related to *H. Hartwegii,* but is a much lower plant, rarely 2 dm. high; it differs mainly from all the preceding species of the group by its silvery pubescence, which extends to both surfaces of the leaflets. Sometimes in depauperate specimens the leaflets are broader and the raceme shorter; this is the case with *Purpus 2477,* which Jones has referred to *A. hypoxylus* S. Wats. The type came from the mountains of Mexico, the locality not indicated. *Ashenborn 343.*

The type of *Astragalus Luisanus, Purpus 3208,* as represented in the National Herbarium, was first determined by Jones as *A. parvus* Hemsley, but afterwards made the type of his new species (see Rev. Astrag. p. 275). It belongs to *H. hypoluca.* On the same page he cited *Purpus 2477* as one of his 'types' of *Astragalus Luisanus,* and on page 278 the same number under *A. hypoxylus.* I have seen three sheets of this number and all are referable to *H. hypoleuca.*

HIDALGO: Tula, *Pringle 6366;* El Salto, *Pringle 9721; Rose & Painter 7089.*—MEXICO: Tultenango, *Rose & Hay 5428;* Paturage a Zapan, *Bourgeau.*—PUEBLA: Puebla, *Arsène & Amable 2020;* Esperanza, *Purpus 2477;* San Luis Tultitlanapa, *3208;* Tepeara, *Rose & Hough 4713;* Chalchicomula, *Pringle 9648.*—COAHUILA:

45 miles east of Saltillo, *Palmer*, in 1880; Buena vista, *Gregg*, in 1848.—QUERETARO: *Arsène 10372, 10574, 10512; Rose, Painter & Rose 9584.*

48. **Hamosa Esperanzae** (M. E. Jones) Rydb. *Astragalus Experanzae* M. E. Jones, Rev. Astrag. 277. 1923. *Astragalus Chapalensis* M. E. Jones, *loc. cit.* The type came from Esperanza, Publa, *Purpus 3207*. The type of *A. Chapalensis*, collected in fruit only, can not be distinguished by the characters given by Mr. Jones. *Palmer 203*, referred by him to *A. Esperanzae*, has as narrow stipules as the type of *A. Chapalensis*.

SAN LUIS POTOSI: Alvarez, *Palmer 203*.—HIDALGO: Pachuca, *Pringle 7644; 6955*.—JALISCO: Chapala, *Rose & Painter 7627*.—CHIHUAHUA: Carretas, *Pringle 1586* (?).

49. **Hamosa parva** (Hensley) Rydb. *Astragalus parvus* Hemsley, Biol. Cent. Am. Bot. 1: 266. 1880. *Astragalus Schaffneri* M. E. Jones, Rev. Astrag. 276. 1923. Notwithstanding the fact that Jones remarks under *A. Schaffneri*, 'This has been referred to *A. parvus* by Watson, but it appears to be quite a different plant,' the writer believes the two identical. In the Columbia College herbarium there is a duplicate of the type of *A. parvus*, *Parry & Palmer 174* and in the herbarium of the New York Botanical Garden there is one of *A. Schaffneri*, viz. *Schaffner 611–815;* the two evidently represent the same plant. Both came from the valley of San Luis Potosi.

50. **Hamosa asperula** Rydberg sp. nov. A cespitose perennial, with a woody root and caudex; stems decumbent or spreading, 1–2 dm. long, purplish, appressed-pubescent with short stiff hairs; leaves 3–5 cm. long, spreading, the rachis pubescent, sulcate on the upper side; stipules connate, deltoid, acuminate, membranous; leaflets 13–23, linear, 6–12 mm. long, glabrous above, strigose beneath, more or less involute; peduncles 3–6 cm. long; racemes dense, 1–3 cm. long; bracts lanceolate, membranous, 2–3 mm. long; pedicels 1 mm. long; calyx black-hairy, the tube 2.5 mm. long, campanulate, the teeth subulate, 2.5 mm. long; corolla purplish, 8 mm. long; banner obovate, strongly arcuate, wings nearly as long, the blades broadly obovate; keel-petals shorter, broadly lunate, the blade nearly semiorbicular, obtuse; pod falcate, strigose, 14–16 mm. long, 2–6 mm. broad and high, tapering at the apex.

The type was named *Astragalus Esperanzae* by M. E. Jones, but differs in the narrow leaflets and the narrower and pubescent

pod. It was collected between Pachuca and Real del Monte, Hidalgo, Aug. 31, 1903, *Rose & Painter 6679* (U. S. Nat. Herb. no. *450235*).

51. **Hamosa hypoxyla** (S. Wats.) Rydb. *Astragalus hypoxylus* S. Wats. Proc. Am. Acad. **18:** 182. 1883.

Dr. Watson thought that it was related to *A. Cobrensis* and *A. arizonicus*. It is not at all related to the former, and only remotely so to the latter. Sheldon included it in his section EREMITICUS, and Jones placed it in MICRANTHI, together with *A. parvus* and other related Mexican species. The affinity is evidently with these, but Jones MICRANTHI is too heterogenous, and this name belongs to *A. Nuttallianus* and related species.

52. **Hamosa Pringlei** (S. Wats.) Rydb. *Astragalus Pringlei* S. Wats. Am. Acad. **21:** 449. 1886. This species is in habit quite unlike the rest, being densely cespitose, with numerous prostrate short stems and large flowers.

CHIHUAHUA: Near the City, *Pringle 79*, in 1885; *Palmer 89*.—DURANGO: Tepehuanes, *Palmer 18*.

Jones included in this group the following species, which are either doubtful or belong to other genera or sections: *A. lentiformis* and *A. Lemmoni*, in which the pod has both margins acute; *A. Madrensis*, *A. ervoides*, of doubtful relationship; *A. Greggei*, which belongs to the section TRICARINATA; *A. Pueblae*, which has a 1-celled pod, and should be referred to *Phaca; A. oxyrhynchus*, which is a *Hesperastragalus; A. Seatoni* and *A. Purpusi*, which apparently are species of *Atelephragma*.

Commelinantia Pringlei

B. C. Tharp

(WITH PLATES 26, 27)

In a former paper,[1] describing the genus *Commelinantia* and re-assigning the species originally described as *Tradescantia anomala*[2] Torrey to the new genus, mention was made of the likelihood that *Tradescantia Pringlei* S. Wats.[3] should also be assigned to *Commelinantia*. At that time scarcity of material prevented a sufficiently detailed examination to warrant more than a suggestion of the probable relationship. In March, 1923, opportunity was afforded me to collect and examine an abundance of fresh material near Monterrey, Mexico, the type locality of the species. In addition to collecting much material for drying, I brought back living plants, which were planted in the open until winter; then some were transferred to the greenhouse, and these have been growing alternately in the open and in the greenhouse, to insure our not losing them. Examination of fresh material of the original collection and continual observation during the three years we have had it growing at Austin has confirmed my earlier suspicion and seems beyond question to warrant the inclusion of this species in the genus *Commelinantia*.

Material was collected on March 9, 1923, on Topo, a low mountain arising out of the valley four or five miles to the northeast of Monterrey. The plant is invariably found on steep northeast or north slopes where it is protected from the intense light and heat which cause the south and west slopes to be dry and arid. In altitude, on Topo, it ranged from near the base to near the top—probably from 1800 to 3000 feet. On March 10 it was again collected, and in more advanced condition, in a range of mountains some twelve miles to the south of Monterrey in the vicinity of one of the Mexican Lead Company's mines. Its altitude there ranged from 2500 to 4500 feet. We climbed to an estimated altitude of at least 5000 feet and apparently passed the higher limit of the species in that vicinity. Time,

[1] Bull. Torrey Bot. Club **49**: 269–275. *pl. 10, 11*. Sept. 22, 1922.
[2] U. S. and Mex. Bound. Bot. 225. 1859.
[3] Trans. Am. Acad. **26**: 157. 1891.

however, would not permit a search of sufficient intensity to warrant this statement as unquestionably certain.

The plant is beyond doubt a perennial. Instead of the aerial normal inflorescence being strictly terminal, as in the case of *C. anomala*, it is strictly a simple axillary peduncled scorpoid raceme, the peduncle differing from vegetative branches in that it does not break through the leaf sheath, even in the lowermost flowering bracts whose sheaths are 4–5 mm. high. The upper bracts have successively shorter sheaths, the uppermost being sheathless. The racemes are fewer-flowered, never more than 5, and no peduncle ever has been observed to produce more than a single seed pod. This pod develops from the first flower to bloom, those which come later falling off. The calyx is essentially similar to that of *C. anomala* except that the sepals are smaller and the veins are more prominent and are slightly reticulated. The petals, however, are equal in size and alike in color, being slightly more decidedly lavender than are those of *C. anomala*. The stamens correspond essentially to those of *C. anomala*, though there is less difference between the posterior and postero-lateral stamens than in the corresponding stamens of *C. anomala*, and the pubescence of the anterolateral filaments is less dense.

A very interesting feature of the plant is the cleistogamous flowers, a feature shared, so far as I can find, by only one other species (*Commelina banghalensis*) of the family, and rare in all monocotyledons. These cleistogamous flowers are usually singly disposed at the ends of true, though modified, branches which invariably break through the sheaths of the lowermost leaves, grow out laterally for several centimeters, then turn abruptly downward, always at a node, carrying the flower below the surface of the soil and developing the fruit in this protected situation. The branches also arise abundantly from nodes beneath the soil surface and spread laterally. The appearance of these flowers is similar to that of the normal ones, except they are smaller, the sepals have no green color, and of course they do not open. Leaves on the filiform branches are usually from one to three in number and are almost or quite reduced to sheaths. The length of these branches is usually determined by the distance of the point of origin above the surface of the soil, except where this point is itself below the surface, in which case the

branch extends horizontally for an indefinite though usually short distance of a few centimeters.

In addition to its elaborate floral provision for reproduction, the plant also propagates vegetatively by means of short rhizomes. It is not uncommon to find clusters of stems apparently representing separate plants thus connected beneath the soil surface. All vegetative parts are succulent and brittle, in this respect resembling the "inch plant" or "Wandering Jew" of window boxes. *C. pringlei* further resembles this plant in the ease with which it may be grown from cuttings.

In view of the clarifying effect of this study of fresh material upon certain more or less conjectured points by means of which the generic description of my other paper sought to provide for this species, it has become necessary to amend that description slightly, to include perennial as well as annual plants, and since *C. Pringlei* has no basal leaves, to omit reference to this point in the generic description.

COMMELINANTIA PRINGLEI (S. Wats) Tharp, Torreya **24**: 52. 1924. Perennial, pea green; *stems* clustered weakly, erect or ascending, finally much branched; *basal leaves* wanting; *lower cauline leaves* reduced to sheaths below soil surface, gradually increasing in size upward, orbicular, abruptly acuminate, sessile or nearly so at the tops of sheaths which are 1 cm. high or less; *upper cauline leaves* increasing in size with increase in height upon the stem, broadly lanceolate, the blades 10 cm. long or less, purplish underneath, abruptly narrowed into short petioles which surmount sheaths about 1 cm. high; peduncle very slender, 1.5–6.0 cm. long; *raceme* simple, the bracts orbicular, obtuse, green with purplish margins, 1–1.2 mm. in diameter; *pedicels* 3–6 mm. long, filiform; *sepals* 3, oblong-lanceolate, obtuse, hooded, keeled, pale green with purplish margins, a prominent mid-rib and two more or less prominent lateral nerves, apically few-ciliate; *petals* 3, equal, rhombic, blue with a decided lavender tinge, 6–8 mm. long by 8–10 mm. wide; *stamens* 6, all perfect, the posterior stamen beset slightly above the middle of the filament with a thick collar of short yellow hairs, bluish below the hairs to the base, yellow or white and curved above to the yellow orbicular anther; the 2 postero-lateral stamens similar to the posterior one except slightly larger and the collars of hairs higher on the filament; the antero-lateral stamens with long slender filaments tapering at both ends and beset below the middle with a collar of fewer but longer hairs than those of the postero-lateral stamens, these hairs are bluish lavender in color, anthers oblong, blue; the anterior stamen similar to the antero-lateral ones except

slightly larger, and with a stouter filament which tapers upward only and is entirely naked; all three anterior stamens usually larger throughout than the three posterior; *ovary* white, attenuate above into a curved white style terminated by a yellowish stigma; *ovules* laterally attached to the central placenta; seeds essentially similar to those of *C. anomala*.

Cleistogamous flowers occur on the lower portions of the stems both above and below the soil surface, appearing in general before the aerial ones, usually singly disposed at the ends of positively geotropic capillary branches, each of which bears from one to three much reduced leaves (usually only sheaths 5–6 mm. long) below the flower; *sepals* similar to above except less hooded, smaller and decidedly purplish throughout; *petals* also similar except progressively smaller downward on the stem, those below the soil surface much reduced; *stamens* slenderer, less hairy, and with anthers much reduced; *ovary* and stigma similar but with a shorter style; *ovules* two in each cavity, superimposed; *seeds* similar to those of *C. anomala* in that the endosperm is separated on one side by a suture which extends to the embryo-cavity; but the seeds from cleistogamous flowers are much rougher, with scalloped, shelving, lateral ridges, and are larger.

Characteristics which unmistakably ally *C. pringlei* to *C. anomala* are: Branches breaking through the leaf sheaths; the exactly similar stamens of four kinds; and the ovaries, ovules, and seeds. The possession of three equal petals and of cleistogamous habit is not shared by *C. anomala;* but the presence and absence of both these characteristics are to be found within the genus *Commelina*, and are certainly not sufficient ground upon which to base a generic distinction.

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Explanation of plates

PLATE 26

FIG. 1. Flowers and stolon. Most of the roots have been cut away in order better to show the stolon. × 1/2.

FIG. 2. General growth habit and cleistogamy. × 1/5.

PLATE 27

FIG. 1. Detail of inflorescence. At right, an aerial flower and developing capsule; at left, an extreme of cleistogamy, developed underground; between intermediate stages just above ground surface. × 3/2.

FIG. 2. Normal aerial vegetative branches and inflorescence habit. × 1/4.

VOLUME 54, PLATE 26
BULLETIN TORREY CLUB

1 2

COMMELINANTIA PRINGLEI

1 2

COMMELINANTIA PRINGLEI

An analysis of the orthic tetrakaidecahedron

EDWIN B. MATZKE

(WITH SIX TEXT FIGURES)

In a series of painstaking and masterly researches Lewis (1923, 1925) has shown that cells of the elder pith, of human adipose tissue, and of the epithelium of the human oral cavity have on an average fourteen faces, and therefore are or tend to be tetrakaidecahedra. Some cells show a striking alternation of hexagonal and quadrilateral faces, suggesting the "plane-faced isotropic" or "orthic" tetrakaidecahedron that Kelvin (1887, 1894a, 1894b, 1904) described. Kelvin stated that space can be filled with equal and similar orthic tetrakaidecahedra, and that, further, they do not possess the unstable tetrahedral angles of the rhombic dodecahedron. And Lewis (1925, 1926) gives data to show that the orthic tetrakaidecahedron has less surface per unit of volume than the rhombic dodecahedron. Unit volumes of this configuration approach then as nearly to the condition of maximum volume with minimum surface as this can be achieved by aggregates of equal and similar units without spaces between. Lewis thinks that this is the pattern or type that cells in masses tend to simulate.

Lewis is not the first to have conceived of the possibility of cells' being tetrakaidecahedral. Thompson (1917) suggests this possibility, though he states that in parenchymatous tissue the dodecahedron is probably the form generally attained. According to Thompson, von Fedorow, in connection with his studies of crystals, described the tetrakaidecahedron before Kelvin, calling it the cubo-octahedron or hepta-parallelahedron; and von Fedorow also assumed that space could be completely filled with such figures. This latter point is also accepted by Tutton (1911).

Recently, however, the writings of both Thompson and Lewis have been criticized by Millis (1918, 1926). In his first article, prompted by Thompson's book, he says of the orthic tetrakaidecahedron: "Space can not be divided into equal volumes of this shape without surplus, or in other words these volumes can not be stacked together without leaving voids.

This may readily be determined by a study of the diedral angles, or practically by constructing a number of the tetrakaidecahedrons and trying it." In a later paper, after Lewis's publications, Millis says again: "The volume described, called the tetrakaidecahedron, does not possess the properties as stated. Equal volumes of this pattern will not fit together without voids, as a brief consideration of the diedral angles, or angles between faces, and the relations of these faces or a practical trial with the models would at once have shown."

The orthic tetrakaidecahedron has fourteen faces, eight hexagonal and six square, all the sides of all the hexagons and all the squares being equal. Three of the sides of each hexagon also form the side of an adjacent square; the other three sides of each hexagon, which alternate with the first three, each form the side of an adjacent hexagon. It is evident then that there are dihedral angles formed by two adjacent hexagons, and by an adjacent square and hexagon; and an examination of the polyhedron reveals that these two angles are different. If now the dihedral angles are counted, it will be seen that there are twelve dihedral angles formed by adjacent hexagons, and twenty-four by adjacent squares and hexagons. Thus there are twice as many dihedral angles formed by adjacent squares and hexagons as by adjacent hexagons.

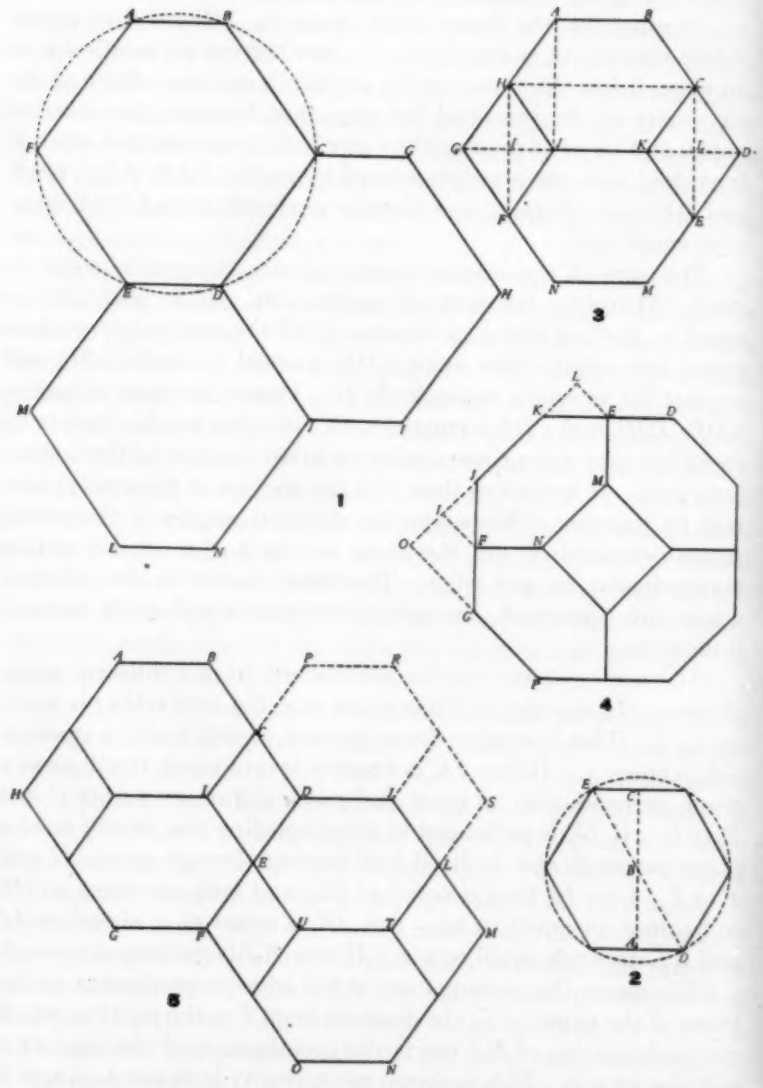
A section through the tetrakaidecahedron perpendicular to any edge shows a figure hexagonal in outline, with four longer and two shorter sides, *ABCDEF*, figure 1. The four longer sides, *BC*, *CD*, *EF*, and *FA*, are formed by lines perpendicular to two opposite and parallel edges of any of the hexagonal faces. This is shown by the line *AC* in figure 2. The shorter sides of the hexagon formed by the cross section, *AB*, *DE*, figure 1, are the same as the edge of a square face, or any line in the square face perpendicular to any edge. Furthermore, the opposite sides, *AB* and *DE*, *BC* and *EF*, *CD* and *FA*, are parallel as well as equal; hence von Fedorow's term hepta-parallelahedron. In addition, any line perpendicular to *ED* at *E* passes through *A;* a line perpendicular to *ED* at *D* passes through *B;* a line perpendicular to *EF* at *E* passes through *C*, etc. Therefore angles *FAB*, *ABC*, *CDE*, and *DEF* are all equal; and likewise angles *BCD* and *EFA* are equal.

The equality of these angles can also be demonstrated by cir-

cumscribing the hexagon, as shown in figure 1. It is also possible to circumscribe the lower right figure in Millis's first paper. While that figure is not simply a cross section perpendicular to an edge, it has the same outline as such a section. Each of the six angles of the inscribed hexagon thus becomes an inscribed angle, and hence is measured by one half its intercepted arc. It is evident that the arcs intercepted by angles *FAB*, *ABC*, *CDE*, and *DEF* are all equal; and likewise angles *BCD* and *EFA* intercept equal arcs.

The sum of the interior angles of any hexagon is equal to 720°. Therefore the sum of angles *ABC*, *BCD*, and *CDE* is equal to 360°, or equal to the sum of all the angles in one plane about any point. But angle *JDE* is equal to angle *ABC*, and angle *CDJ* is equal to angle *BCD*. Hence the sum of angles *CDE*, *JDE*, and *CDJ* is equal to 360°; in other words, there is no space left over when these angles are fitted together in the fashion indicated. It is obvious then that the sections of these polyhedra will fit together. Moreover the dihedral angles of the orthic tetrakaidecahedron are the same as the angles of the section perpendicular to any edge. Therefore, as far as the dihedral angles are concerned, the tetrakaidecahedra will stack without interstices.

The same subject can be approached from a different point of view. In figure 3, if *AB* is equal to x, *GA* (not *GHA*) is equal to $x\sqrt{3}$. This is evident from figure 2, in which *AC* is equal to *GA* in figure 3. If line *JK* in figure 3 is prolonged, it will meet a plane perpendicular to itself and passing through points *C* and *E* at *L*. If *JK* is prolonged in the other direction, it will meet a plane perpendicular to itself and passing through points *H* and *F* at *I*. Line *IL* then is equal to *HC*, and both are equal to *DE* in figure 2, or equal to $2x$. But *JK* is equal to x; therefore *IJ* and *KL* are each equal to $x/2$. If now *KJ* is prolonged through *I* till it meets the prolongation of the edge perpendicular to the plane of the paper at *G*, the distance from *I* to the point at which the prolongation of *KJ* meets the prolongation of the edge at *G* will also be $x/2$. This is shown more clearly in figure 4, in which the lettering is the same as in figure 3. There it is obvious that *JI* is equal to *IO*, which meets at *O* the prolongation of edge *PG* (the edge perpendicular to the plane of the paper at *G* in figure 3). *JO* in figure 4 is therefore equal to $2x/2$ or x. If now a



FIGS. 1–5. Relation of orthic tetrakaidecahedra and of their faces and angles.

plane section is cut through points A, G, N, in figure 3, it will also pass through points M, D, and B in figure 3, and through points G, N, M, and D in figure 4. Point J can be projected on this plane surface; and if this point is called J', GAJ' in figure 3 becomes a right triangle, of which one side is GA, equal to $x\sqrt{3}$, and another GJ', equal to x.

The cosine of angle AGJ' is equal to $x/x\sqrt{3}$, or $\sqrt{3}/3$, or .57735, and that angle, AGJ', is 54° 44′ 8″. The dihedral angle AGN in the tetrakaidecahedron is twice angle AGJ', or 109° 28′ 16″.

The sine of angle GAJ' is equal to $x/x\sqrt{3}$, or $\sqrt{3}/3$, or .57735, and the angle GAJ' is 35° 15′ 52″. The dihedral angle GAB in the tetrakaidecahedron is obviously 35° 15′ 52″ plus 90°, or 125° 15′ 52″. When the tetrakaidecahedra are fitted together as suggested by the sections in figure 1, two of the dihedral angles GAB and one dihedral angle AGN meet to fill up space about any of the edges of the figure, and they total 360°, leaving no space unoccupied. From a consideration of the dihedral angles, then, we are prompted to conclude that these polyhedra can be stacked without leaving voids.

Two tetrakaidecahedra may be placed together so that two hexagonal faces coincide, and that three edges of one of these hexagons which also form edges of squares coincide with three edges of the other hexagon which also form edges of adjacent hexagons. This arrangement is shown by the polyhedra $ABDFGH$ and $DJMNOF$ in figure 5. In the solid figure a line in the plane of face FED, perpendicular to ED at E, forms, with edge EI, the dihedral angle between a square and a hexagonal face. If we call such a dihedral angle α, and the dihedral angle between two hexagonal faces β, it has been shown above that $2\alpha + \beta = 360°$. Edge EI, then, forms an angle α with face FED at E, and forms an angle of 90° with edge ED at E. This fixes the position of edge EI in space.

If now a third tetrakaidecahedron is placed upon $DJMNOF$, as indicated by the dotted lines in figure 5, so that a hexagonal face of the third polyhedron coincides with face $DJLTUE$, and the edge at DE also forms the edge of a square face, then another edge of the square face, which we may call EI', is perpendicular to ED at E. It is also true that EI' forms an angle α at E with a line in face $DJLTUE$ perpendicular to ED at E.

And the dihedral angle at E in the polyhedron $DJMNOF$, formed by the two hexagonal faces whose common edge is ED is β. Adding these two angles we find that EI' makes an angle of $360° - (\alpha + \beta)$, or makes an angle α with face FED at E. Therefore EI' is fixed in space in the same position as EI, and hence they coincide. Thus it is evident that the tetrakaidecahedra will fit together without voids.

This is also indicated by the photograph in figure 6, in which fourteen of these polyhedra, modelled in wax, surround a central tetrakaidecahedron.

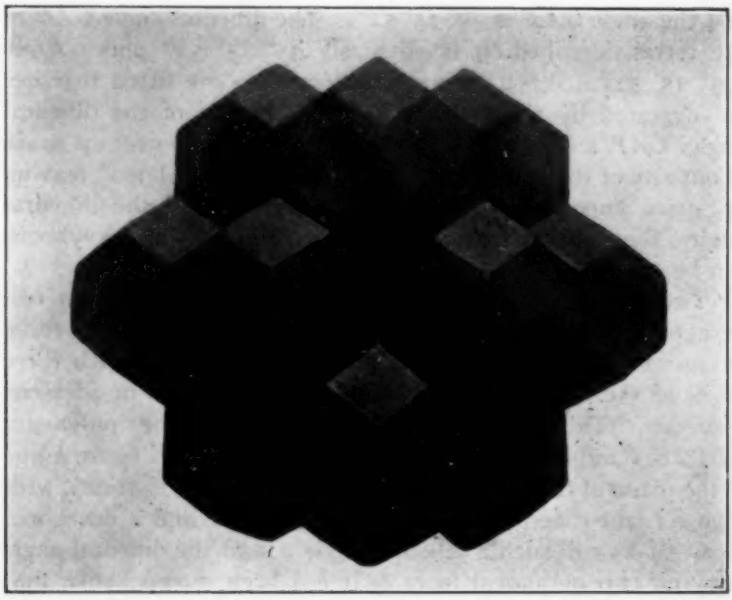


FIG. 6. Fourteen orthic tetrakaidecahedra surrounding a central one.

Millis says further: "Lord Kelvin's subsequent discussion of similar volumes with warped or distorted faces, which is referred to in Mr. Lewis's original papers, indicates that the error was later recognized by its distinguished author, though the subsequent treatment was far from convincing." Three of Kelvin's publications are cited in Lewis's papers, those of 1887, 1894b, and 1904. In the first of these, Kelvin discusses, in addition to the orthic tetrakaidecahedron, in which all the faces are plane sur-

faces, another tetrakaidecahedron having six quadrilateral plane faces. The eight hexagonal faces each have their six corners and three long diagonals in one plane, but the area between the diagonals curved. In this way a figure is obtained which has the angles between all the adjacent faces 120°, and hence is more stable than the orthic tetrakaidecahedron with its two kinds of dihedral angles. "The theoretical conclusion as to the angles for stable equilibrium (or pure minimum of the mathematical problem) therefore becomes, simply, that every angle of meeting of film surfaces is exactly 120°." Thus in his first discussion of the subject Kelvin described a tetrakaidecahedron with curved surfaces, not because the orthic figure would not stack without voids, but because the angles between the faces were not 120°. And his researches and those of Plateau (1873) led him to conclude that three films meeting in an edge would assume that angle.

The "Robert Boyle Lecture" (delivered in 1893, printed in 1894 and 1897) and the reprint of it in the appendix to the "Baltimore Lectures" (1904)—the only other publications of Kelvin cited by Lewis—contain no statement by the well known mathematician and physicist that orthic tetrakaidecahedra will not fit together without leaving unfilled spaces. The "warped and distorted faces" referred to by Millis, are apparently the curved hexagonal faces which Kelvin described in his first paper. If there is any statement in the very voluminous writings of Kelvin to the effect that orthic tetrakaidecahedra are unstackable, it has not found its way into the literature of the subject. In 1904 the "Baltimore Lectures," which were delivered in 1884, were published, with the "Robert Boyle Lecture" in the appendix. Three notes to the latter dated 1896, are added, but none on the disputed point. Several of the Baltimore discussions were written afresh in 1901, 1902, and 1903 for that edition, suggesting, at least, that from 1887 until 1896, and probably until 1904, Kelvin did not change his opinions on the subject; and there seems to be no reason for such a change.

The tetrakaidecahedron was useful to von Fedorow in the development of his theory of crystal structure; and the space-lattice concept developed for crystals might also serve, in a slightly different sense, for tissue systems, conceiving of homologous points in the cells or their walls as forming the points of

the lattice. Different tissues, then, would in many cases at least have different symmetry patterns, and intermingling tissues would disclose interpenetrating space lattices.

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